INTRODUCTION

Erik M. Lammerts van Bueren

The seminar 'The balance between biodiversity conservation and sustainable use of tropical rain forests' is organised to take stock and present the result of more than 10 years research and activities within the MOFEC-Tropenbos-Kalimantan Programme.

Over the years the programme has expanded and slightly changed its focus. In the late eighties after the devastating forest fires the primary focus of the programme was on forest rehabilitation. Regeneration of species of the Dypterocarpaceae family was a major problem to be solved. With success techniques and methods were developed to use more effectively natural regeneration and to produce vegetative seedlings. To contribute to the well-being of the local population and to offer them alternatives for encroachment in the forest, agroforestry systems were developed. Gradually the programme embarked on the development of sustainable forest management systems for timber exploitation in primary and disturbed natural forests.

Almost simultaneously the programme became more involved in aspects of nature conservation as a result of the orang utan reintroduction programme and studies of biodiversity.

Together with our Indonesian partners we are proud to know that the programme has not only produced valuable scientific and technical results, but also has managed to train numerous scientists, forest managers, forest technicians and rangers through PhD, MSc education and practical careers at the Wanariset.

We hope the organisation of the seminar has stimulated researchers to complete or complement their publications with documents and presentations. We expect the seminar itself to be instrumental in integrating the results into additional meaningful information and guidelines for sustainable forest management. Finally we expect the seminar will provide some directions as to the future development of the MOFEC-Tropenbos-Kalimantan Programme.

The Tropenbos Foundation, Wageningen, the Netherlands

INTRODUCTION TO THE NWO PRIORITY PROGRAMME BIODIVERSITY IN DISTURBED ECOSYSTEMS

The general goal of the priority programme 'Biodiversity in disturbed ecosystems' is to stimulate research that:

- makes us understand the changes in species and genetic diversity as a function of ecosystem disturbance and
- promote the knowledge how (disturbed) ecosystems function.

The programme has the aim to formulate specific recommendations for natural conservancy and the restoration and sustainable use of particular disturbed ecosystems. The program has three themes:

1. comparative research on species distribution at different trophic levels in pioneer communities and disturbed habitats
2. organisation, distribution and significance of genetic variation and demographic structure in relation to chances of survival of (key) species
3. identification of key species and mutual interactions, and the relationship between the level of biodiversity and the functioning and stability of ecosystems

The emphasis will be laid on the integrative aspect and the translation to policy and management advice. The programme runs since 1994 and will continue till 2004, with a total budget of 8.7 million guilders.

The program is multidisciplinary and includes field and laboratory work as well as theoretical and empirical research. The results of the projects should contain general conclusions. Most of the research in the field is done in tropical lowland forests. The final location depends on the availability of specific detailed knowledge and expertise. There is a strong preference to participate in integrated programmes. Projects are located near or at sites hosted by Tropenbos in Kalimantan, Indonesia (S.E. Asia), Cameroon (Africa) and Guyana (Latin America).

A number of projects (Arphola butterflies, Myccorhizae fungi, terrestrial flatworms and Mallotus genera) studies the biodiversity of the specific groups in both undisturbed and disturbed ecosystems (such as the post-fire forests in Kalimantan, 1998). The effects of disturbance can only be understood if knowledge on the biodiversity on all trophic levels of an ecosystem is available, from primary producers up till top predators.
Other research projects are focussed in the biodiversity, genetic population structure and population dynamics of pioneer species, who dominate the early succession stages of a forest. Pipturus (Urticaceae) was selected as a model taxon. An example of the policy oriented research is the project in which it is studies till what level forest biodiversity can be maintained in combination with Hevea (rubber) production. In this research the intensity of plantation management (from primary forests to mono-culture) are compares with production and biodiversity levels.
A number of projects focuses on population genetics and evolutionary biological processes as part re-colonisation and regeneration and the consequences of population fragmentation. These research projects take place in Indonesia (Krakatau), Africa and Latin America with (fig)trees, fig wasps, the African buffalo and Myccorhizal fungi as main research topic

Finally there are some integrative studies that focus on the integration of the output of the different research projects into models of the effects of disturbance on the biodiversity in an ecosystem. The models integrate not only the results obtained by the research projects of the programme but also results from affiliated research projects by ICRAF and Tropenbos. The models will be tested in the field in other projects on Kalimantan from research partners (Tropenbos, ICRAF). The final results might also feasible for the Dutch environment.

A theoretical research project will focus on the explanation and definition of the different concepts (like ecosystem, biodiversity, key species) as used in the programme. At the same time it will pay attention to the relation between the results of the research projects (output) and the practical implementation (uptake).

Through a newsletter and annual seminars both the researchers within the programme as outside the programme are updated on the most recent progress in the programme. For an overview of the projects and additional information please refer to the Internet site at:
http://www.nwo.nl/english/alw/programmes/disturbedbiodiversity

THE MOFEC-TROPENBOS PROJECT AND INTERNATIONAL PRIORITIES IN BIODIVERSITY RESEARCH

Pieter Baas

SUMMARY

The ongoing biodiversity research of the MOFEC-Tropenbos-Kalimantan project is discussed in the framework of international programmes and initiatives such as Diversitas/Systematics Agenda 2000-International, the Global Taxonomy Initiative and the Global Biodiversity Information Facility. It is argued that specimen-based biodiversity information systems should now be established according to the CONABIO model to build on the successful botanical exploration of the past 10 years, and to strengthen the supra-regional role of the Wanariset Herbarium in biodiversity and forestry research programmes and in environmental impact assessments throughout Kalimantan.

INTRODUCTION

Sustainable use and conservation of the biodiverse resources of tropical forests are among the core targets of the MOFEC-Tropenbos project in East Kalimantan. The biodiversity subprogramme has been active from the late eighties and has resulted in a number of major publications (Keßler and Sidiyasa, 1994; 1999, Keßler *et al*., 1992; Sidiyasa, 1998; Sidiyasa *et al*., 1999; Bodegom *et al*., 1999; van Valkenburg, 1997; 1999). The most valuable, and hopefully most durable result of the plant diversity exploration and research is without doubt the Wanariset Herbarium, a well-curated reference collection of now well over 12,000 specimens containing a wealth of information on the occurrence, distribution and ecology of plant species of the lowland Dipterocarp rainforest and its secondary forest derivatives (Sidyasa *et al*., 1999).

In this paper I will briefly explore how the MOFEC-Tropenbos biodiversity programme and the Tropenbos Biodiversity Research Priorities in general (Lammerts van Bueren and Duivenvoorden, 1996) relates to international initiatives and priorities, and how it helps to underpin the aims of the Convention of Biological Diversity (CBD), and the Indonesian Biodiversity Action Plan derived from it.

GLOBAL INITIATIVES AND PRIORITIES

The CBD aims at conservation and sustainable use of biodiversity, and calls for equitable sharing of the benefits of biological resources. It calls for research on, i.a.:

- identification and monitoring of components of biological diversity that are important for conservation and sustainable use;
- programmes for scientific and technical education and training on identification for the benefit of conservation and sustainable use;

- appropriate environmental impact assessments of all human interference that is likely to have significant adverse effects on biological diversity.

From the early days, the Conference of the Parties (COP) to the CBD recognised the so-called taxonomic impediment: insufficient knowledge of species diversity, caused by locally high species numbers and a shortage of taxonomic expertise, that hampers biodiversity analyses at all levels from populations up to ecosystems, especially in tropical megadiverse regions such as East Kalimantan. In Indonesia the taxonomic impediment is compounded by a weak infrastructure of systematic biology, with most taxonomic capacity centred around the major collections of Puslitbang Biologi of LIPI on Java, and very little university training in taxonomy at Indonesian universities. Despite calls for strengthening botanical, zoological, mycological and microbial taxonomy in the Biodiversity Action Plan of Indonesia there is still a very serious shortage of autochtonous taxonomic expertise. This is by no means compensated by sufficient allochtonous human resources studying Indonesian's biodiversity in of major biological collection centres such as those of Canberra, Edinburgh, Kew, Leiden, London, Harvard, Paris, etc: in many global research centres taxonomic capacity is also on the decrease (Baas, 1998; 1999; Parnell, 1996).

At the global level the taxonomic impediment will hopefully be resolved through the Global Taxonomy Initiative (GTI, url at http://www.biodiv.org/sbstta4/index.html and http://www.anbg.gov.au/abrs/flora/webpubl/london.html) a set of proposals adopted by the 4th COP of the CBD in Bratislava, 1998. The GTI stresses the importance of the biodiversity information base contained in large biological collections, capacity building, information systems, support for ongoing Flora and Fauna Projects (such as Flora Malesiana and Fauna Malesiana), stable naming of taxa, and support for the Global Biodiversity Information Facility (GBIF, url at http://www.york.biosis.org/gbif/presentn/index.html). Diversitas, the international programme for biodiversity research, together with international partners have staged a number of recent workshops to develop criteria for priority setting and on national and regional strategies and methodologies for biodiversity inventory (Diversitas, 1999; Australian Biological Resources Study, 1998; American Museum of Natural History, 1999 see also url at http://www.icsu.org/DIVERSTAS/). The most significant of these is perhaps the Diversitas report from 1999: "Implementing the GTI - Recommendations from Diversitas element 3/Systematic Agenda 2000 - International) including an assessment of present knowledge of key species groups". A panel of twelve specialists from all over the world, convened by Lily Rodriguez (Lima, Peru) and Henk Beentje (Kew, UK) provided a best possible estimate of the total number of described and as yet to be discovered and named species (Table 1).

Table 1 Number of described species, and percentage of the estimated total number of species they represent (after Diversitas, 1999; for viruses and bacteria any estimate of undescribed species numbers would still be pure speculation).

Viruses	4,000 (?%)
Protozoa	23,000 (5%)
Bacteria	7,000 (?%)
Fungi	72,000 (5%)
Algae	40,000 (17%)
Mosses	21,000 (80%)
Vascular Plants	270,000 (90%)
Invertebrates	980,000 (45%)
Vertebrates	52,000 (90%)
Total described	**1,459,000**
Estimate of total number of described and undescribed species: 5-6 million	

The resulting sum total of species of ca. 5-6 million species (assuming conservative estimates of 200,000 to one million species of viruses and bacteria) falls well short of the circulating estimates of 10-80 million species of organisms on our planet.

It should be stressed that although about one and a half million species have been formally described (and taxonomically revised to some extent, so that the estimates by the expert panel could take synonymy into account), most of these described species are by no means well-known and biologically understood. Moreover, information on them can often only be accessed by specialists in scattered literature published over the last 250 years, and only available in a few major libraries. This, taken together with the estimated number of ca. four million species yet to be discovered, named, described and classified, implies that priority setting among the small international community of systematic biologists is of the utmost importance. This applies especially to tropical floras and faunas such as those of Kalimantan where percentages of poorly or completely unknown species is much higher than the global figures listed in table 1, and where total number of species per surface area (alpha diversity) as well and differences in species diversity along geographical or ecological gradients (beta diversity) are also among the highest in the world.

Diversitas/Systematics Agenda 2000 - International (Diversitas, 1999) recommends the following criteria for priority setting:

- taxa of economic value;
- taxa characterising ecosystems (or playing a key role in ecosystem functioning);
- taxa of threatened areas (or: of major conservation concern);
- taxa with indicator value for ecosystem fitness or for any other relevant ecological or environmental parameters.

THE MOFEC-TROPENBOS RESPONSE

The above criteria appear to apply admirably well to all ongoing and completed MOFEC-Tropenbos Biodiversity projects. The taxonomic and floristic manuals published so far deal with species that define the structure of the ecosystem: trees, that in turn are important for their economic potential als timber trees or producers of non-timber forest products (NTFPs), and include a number of endangered species. Commercial logging, slash and burn cultivation, other land use changes, and the catastrophic forest fires of the early eighties and late nineties of the previous century have resulted in a very high proportion of seriously degraded forest lands in Kalimantan. The focus of the biodiversity research projects on disturbed ecosystems is entirely justified, and will hopefully lead to better understanding and management of their regeneration (Keßler *et al*., in prep.).

Species with indicator value for human disturbance and regeneration are currently subject of a number of research projects, especially in the NWO-MOFEC-Tropenbos co-operative priority programme on Biodiversity in Disturbed Ecosystems (see papers elsewhere in the programme by Cleary, Eichhorn, Lammertink, Slik, Verburg). The various tree inventories underpin the important studies on forest dynamics that are so urgent to understand and assist the regeneration of once or twice burnt forests in Kalimantan (see papers by Susilo, Murmati, Priadjati, and Irsyal Yasman).

Other aims of Diversitas, the GTI, and Systematics Agenda 2000-International have also been well served by the Wanariset Herbarium team. Capacity building ranks highest in this respect: a number of PhD and MSc projects have been successfully completed (e.g. Sidyasa, 1998; van Valkenburg, 1997; Bodegom *et al*., 1999) and a large number of theses is in preparation. Most members of the Herbarium team were trained in all aspects of modern herbarium management and database management in Leiden.

The GTI also aims to create easily accessible biodiversity databases This has been served by electronically cataloguing the entire Wanariset herbarium in BRAHMS (Sidyasa *et al*., 1999). This database should in my view be combined with other collections-related data from East Kalimantan, in the same way as the successful CONABIO organisation in Mexico has done for both herbarium specimens and zoological accessions in different museums and herbaria to obtain patterns of known and potential biodiversity richness. Specimen-based Biodiversity Information Systems have a great range of applications, including the prediction of fire-hazards in relation to decreased species diversity, or predicting comprehensive distribution areas from patchy collecting data (Jorge Soberon, pers. comm.; see also http://www.conabio.gob.mxl).

CHALLENGES AND OUTLOOK

Despite these positive results and prospects we should not loose sight of the fact that the small Wanariset Herbarium team cannot cope with collecting, curating, and documenting all plant biodiversity of SE Kalimantan. Nevertheless Wanariset is now the unrivalled regional centre for tree species information - not only relevant for growth-and-yield studies and forest rehabilitation of the MOFEC-Tropenbos programme but also for other national and international Forestry and Biodiversity Research programmes in Kalimantan (e.g. of CIFOR and GTZ, and the Berau Forest Management Project Berau). Wanariset if sustained or strengthened could serve these other programmes very well in future collaborative projects, where each individual programme would have its own profile and unique strengths. Synergy among the biodiversity and forestry programmes in Kalimantan should also feed back to other ASEAN initiatives and programmes, such as the Indonesian Biodiversity Action Plan, Flora and Fauna Malesiana, PROSEA, the ASEAN Biodiversity Centre in Los Banos, and ultimately the Global Biodiversity Information Facility.

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THE BALANCE BETWEEN BIODIVERSITY CONSERVATION AND SUSTAINABLE USE OF TROPICAL RAIN FORESTS

POLICY-RELEVANT FOREST RESEARCH

Jeffrey Burley

ABSTRACT

Research forms part of a continuum that ranges from pure and strategic research through applied and developmental stages to widespread application of the research results. The MOFEC-Tropenbos programme in Kalimantan covers a large part of this continuum; it has developed as a multi-disciplinary approach to problems in forest policy and management. This problem-orientation is a notable feature of the programme. Too often research is conducted in a vacuum, in a researcher's own narrow field, and does not address major policy issues. Many individual scientists, research institutions and development agencies ignore the need for science to contribute to the policy process and to address the problems or wishes of all stakeholders in the forest. In particular, there has been marked reluctance by socio-economic and biophysical scientists to address issues on a multi-disciplinary and inter-disciplinary basis.

Biological diversity and its conservation are fundamental to the achievement of sustainable use of tropical rain forests but biological diversity varies between ecosystems, species, populations, genes and alleles; sampling for biodiversity must take account of variation due temporal and geographic effects. Sample sizes may be reduced by the identification of various indicators including species-area relationships, ecological and economic indicator species, taxic groups and functional groups. A range of methods for assessment and monitoring of biodiversity include traditional forest inventory and vegetation analysis supported by remote sensing techniques and recent molecular methods.

Indonesian forests are among the world's major resources of biodiversity, of human cultural variability and of economic, social and environmental benefits. Yet Indonesia has been the focus of global attention because of its extensive forest fires and deforestation for the establishment of plantations. The MOFEC/Tropenbos project, like many Tropenbos-supported projects in other countries, has sought to achieve widespread agreement on the concept and components of sustainable forest management, to develop methods for the integration of production with conservation, and to recognize the linkages between research, policy and management. This international workshop provides an opportunity to examine progress in achieving the project's objectives against a background or baseline of experience elsewhere.

INTRODUCTION

Mr Chairman, distinguished guests, ladies and gentlemen, it is a very great pleasure and privilege to be invited to address this eminent gathering and to bring the greetings of my colleagues in the

International Council and Executive Board of the International Union of Forestry Research Organizations (IUFRO). Although it is over fifteen years since I was last in Balikpapan, I have known of the programmes and outputs of Tropenbos since its inception and I would like to congratulate the entire institution for its undoubted successes; in particular I am delighted to be here to share in this tenth anniversary of the programme in Indonesia and to congratulate the Indonesian collaborators for their efforts also. Finally I would like to thank Tropenbos, the International Ministry of Forestry and Estate Crops, and the Dutch Organization for Scientific Research for inviting me personally to this meeting. I look forward to hearing how the Tropenbos-Kalimantan project has contributed to the issues that I address below.

As President of the International Union of Forestry Research Organizations (IUFRO), I hope you will allow me a minute to explain the structure and functions of the Union for those of you who are not familiar with it. IUFRO is the oldest, non-governmental, collaborative research organization having been founded in 1892. It now comprises nearly 700 member institutions in 109 countries with 15,000 scientists working collaboratively and voluntarily in 276 Divisions, Research Groups and Working Parties. Throughout this century the Union has stimulated and supported excellent research in a wide range of scientific topics. However, IUFRO has now established Task Forces to encourage the integration of such research and to present the results in ways in which policy-makers, forest managers, the media and public can understand. At its quinquennial Congress in Malaysia during August 2000, IUFRO scientists will produce state-of-knowledge reports on many major issues to indicate both the current available information and any need for new research.

One Task Force has been created specifically to examine the interface between research and policy. Increasingly, researchers have to recognize that, with very few exceptions, totally unrestricted (‘blue skies’) research is now unlikely to receive financial support; most research must be directed towards real problems, some of which are applied and some of which are relevant to policy-making and strategic planning. Researchers do not expect to make policy but they do wish that policy-makers base their decisions on available information and on the recognition of the likely impact of these decisions. Consequently, IUFRO has sought recently to have a place and play a role in the major international policy fora and with the important international agencies; at the same time scientists in individual member institutions should be seen as legitimate stakeholders in national policy processes.

THE ROLE OF FORESTS

It is now widely recognized that forests and trees offer three sets of benefits to mankind:- economic products include solid wood, reconstituted wood, chemical derivatives, energy (fuelwood, charcoal, liquids and gasses), fodder, forage, food and other non-wood products; environmental benefits include soil conservation, water flow and flood control, climate amelioration, site rehabilitation and biodiversity conservation; social benefits include the provision of employment, income, capital, diet diversity, human and animal health, while also reducing risk and seasonality in rural communities, contributing opportunities for gender equalization, and reducing artificial inputs in land use systems. Some of these products and services are easily valued in market terms but others are difficult to evaluate including biodiversity and genetic resources at all levels. Frequently meeting the demands for these various products and services causes conflict in land use policy and forest management; the search for sustainable forest management must devise silvicultural and harvesting methods, within a supportive socioeconomic policy framework, to meet these varying demands.

RESEARCH IN DEVELOPMENT

The continuum from research to application. Research does not stand alone. It is part of the continuum from basic, strategic, applied and adaptive research to widespread application; the MOFEC/Tropenbos programme in Kalimantan has covered a large part of this continuum. However, research itself is heterogeneous in many respects; much of the discussion below follows from an invited paper for the 50th anniversary conference of the New Zealand Forest Research Institute in 1997 (Burley, 1999).

Research components. To be effective research requires the design of appropriate experiments or surveys, the collection of raw data and the relevant statistical or graphical analysis of these data. The resultant information requires further interpretation and judgement to inform decisions on future actions. As forestry becomes more global and receives higher political attention, research increasingly has to take account of public benefits and the results of research need to be presented in ways that the public and policy-makers can understand. Furthermore, there is a great need for inter-disciplinary approaches to the solution of political, managerial and public problems and a corresponding need for biophysical and social scientists to change their attitudes, to work together and to begin to understand each other's approach to research design and analysis.

Geographic location. Researchable topics may be of importance globally, regionally, nationally or locally and the stages of research are variously appropriate to these levels. Much of the research of the Tropenbos projects is obviously of direct local and national importance but other activities have a much more regional or even global significance, particularly those that deal with biodiversity assessment methods, forest inventory and management methods and the role of forests and trees in supporting agriculture.

Stakeholders. Traditionally research has been planned and conducted by more or less well-trained researchers and often the results have been shared only with other researchers, frequently through journal publications. With the increasing need for multiple forest benefits for a greater range of beneficiaries, research needs to be diversified and more interdisciplinary. Major stakeholders include international development agencies, national governments and organizations, industries and human populations that depend on forests or forest products for their survival, welfare or economic growth, including those wood processors and users who are remote from the forest.

Research providers and funders. Research is provided by an equally varied group of institutions. These include the advanced research institutes or universities which frequently undertake basic research, the less advanced institutions and universities which conduct some basic but largely strategic research, and field stations of both government and industry research departments that offer applied and developmental work. Not all of these are necessarily the sources of finance but in addition to national and international agencies, a number of non-governmental organizations and charities do fund significant research. It is often difficult for the individual researcher, or indeed an entire research institution, to identify and form alliances with such funders. Research is notoriously susceptible to restrictions in finances yet we need sustainability in research *per se* that requires support far beyond the modern 3- or 5-year project concept.

THE SPECIAL CASE OF BIODIVERSITY

Since the United Nations Conference on Environment and Development in 1992 the importance of biodiversity and its conservation has been widely recognized (Heywood, 1995). The Convention on Biological Diversity recognizes that biological resources should be made freely available for sustainable use subject to fair and equitable sharing of benefits from the use of genetic resources; this is confounded with the need to recognize the intellectual property rights of those who originally conserved a resource or its information and of those who work towards its genetic improvement and application. To undertake sustainable conservation of biological diversity and the wise use of genetic resources, we need techniques for the assessment of biological diversity and for its conservation. We seek to conserve biological diversity for ethical, aesthetic, ecological and economic reasons but all of them need the basic information, recognizing that biological diversity itself refers to ecosystems, species, populations, genotypes and genes.

Levels of biological diversity. Genetically based biological diversity incorporates diversity within ecosystems (alpha-diversity), diversity between ecosystems (beta-diversity), and diversity in a region or country (gamma-diversity). Further, it incorporates differences between species (number of taxonomic groups, number of species, abundance/rarity, degree of endemism, size/form classes and trophic levels). Within a species genetic diversity includes the number of genes, the number of alleles of each, and the frequency or rarity of each allele, including the variation of all these elements between different populations. An understanding of these intra-specific parameters is fundamental to the design of sampling strategies and conservation management.

Reasons for measuring and monitoring biological diversity. Depending on the level concerned, a knowledge of biological diversity contributes to:- understanding ecosystem structure and function; conserving and developing germplasm through breeding; monitoring the impact of management, logging and environmental change; prioritizing areas for conservation; and facilitating mandatory reporting to governments, the United Nations and various conventions.

Sources of variation in sampling biological diversity. A single count of the number of species or the numbers of individuals within species in a given sample is totally inadequate as an estimator of biological diversity. Diversity may change and different sampling procedures may be necessary because of temporal and geographic effects and because of variable interactions between species (Burley and Gauld, 1995). Temporal effects include the historical date, individual growth stages of plants and animals, seasonal and annual variation, mobility of animals, and community seral stage. Geographically biological diversity varies with different physical positions in a single tree and geographic scale. Interactions between species require a thorough understanding of the ecology of an ecosystem including a knowledge of the environmental factors, age structure and seral stage, the presence of real or virtual keystone species, and predation, parasitism and mutualism. This is particularly important in tropical rain forests and several of the papers at this workshop will address different aspects of the sampling problem.

Indicators of biological diversity. It is clearly not possible to assess all the species or individuals in a given site. A number of indicators have been developed for various forest types to reduce the sampling requirement. These include the derivation of species-area relationships, the identification of keystone species, ecological indicator species, economic valuation species; taxic groups and functional groups. Considerable research on some of these has been conducted in Indonesia.
Assessment methods. The forests of Indonesia are among the world's most intensively studied from

the taxonomic viewpoint but still we lack considerable knowledge of the species and their relative distributions; we know much about the trees, plants, birds and larger insects but virtually nothing about the microbial diversity. A range of methods is available to assist in the assessment of biological diversity at all levels including traditional forest inventory and vegetation analysis supported by remote sensing techniques, geographical information systems and geographical position systems; the development of radar systems permits studies below canopy level and in all conditions of cloud cover. Several papers at this workshop will consider these in the context of East Kalimantan. Recently developed molecular methods (Karp, 1998) have potential applications in taxonomic and genetic evaluation of biological diversity; these include systematics, genecology, population structure, breeding structure, genetic evaluation, fingerprinting and pedigrees, physiology of resistance and tolerance, and the genetic control of specific properties. Some molecular techniques permit the identification of microbes without culturing them (by sequencing and culturing ribosomal RNA genes from natural environments); it is probable that less than 10% of microbial diversity has actually been cultured (Ward, Weller and Bateson, 1990).

In support of these assessments the monitoring of biological diversity over time and managerial change requires site integrity monitoring and site quality monitoring (Goldsmith, 1991). These include:- the effects of climatic change, pollution, irrigation, salination or over-grazing; changes in numbers and distribution of rarities and endemics; recording the richness of valued biotopes. Throughout the assessment and monitoring process, local human populations should be involved.

Information. For many of these subjects information is already available or is rapidly accumulating in libraries and databases in developed countries yet it is not easily accessible, particularly to scientists in developing countries; concerted efforts are now being made to provide international information systems as ‘first-stop shops’ for enquiries about biodiversity (the Global Biodiversity Information Facility supported by the Organization for Economic Cooperation and Development) and forestry (the Global Forestry Information Service, under development by a number of agencies under the aegis of a IUFRO Task Force).

CONCLUSION

The forests of Indonesia are recognised as housing large proportions of the world’s biological diversity while contributing a major proportion of the country’s economic and social welfare. However, it is also well recognised that extensive deforestation has occurred through forest fires and the establishment of plantations. Timber resources are becoming exhausted and logged forest land is being used for timber plantations (e.g. *Acacia* species) and oil palm plantations; the current area of palm is 2.4 million hectares and it is expected to reach over 5 million hectares in a few years. Thus, the conservation of areas of natural forest requires a clear knowledge of the ecosystem structure and function, the value of the biological diversity within the forest and dependent on it, and mechanisms to manage the forest for multiple benefits and multiple stakeholders. With adequate assessment of biodiversity and estimation of all forest values it is possible to develop a balance between biodiversity conservation and use of forest resources. The work of the MOFEC/Tropenbos project has already produced valuable information to meet this aim and now needs to interact with the policy-makers and forest managers to ensure that research information is put into practice with a supportive background of environmental and social policies.

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VEGETATIVE PROPAGATION TO ASSURE A CONTINUOUS SUPPLY OF PLANT MATERIAL FOR FOREST REHABILITATION

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ABSTRACT

Species of the Dipterocarp family dominate the canopy of the tropical rain forests in the lowlands of Kalimantan, Indonesia. Many species are economically very important and, as a consequence, are threatened by logging activities. Enrichment planting after logging with dipterocarp species is feasible and ecologically acceptable. The species choice depends on the goals of the forest manager. A continuous supply of plant material is needed for plantation activities, forest rehabilitation and reforestation. Unfortunately, continuous availability of dipterocarp seeds is hampered by unpredictable fruiting seasons, irregular fruiting (only once in 4 to 13 years), recalcitrance of the seeds and fretting by insects and other animals. Collection of wildlings may help to solve the problem only during the first two years after the fruiting season.

The MoFEC-Tropenbos Kalimantan Project at the Wanariset Samboja Research Station has been developing methods for vegetative propagation of dipterocarp species since 1987. By using these methods, planting stock can now be produced continuously. In this paper, the main research results will be discussed.

Concession holders and other forest institutions have sent personnel to the Wanariset for training courses to learn these vegetative propagation methods for application in their forest concessions. This training programme has been running since 1993. An evaluation of the effects of the introduction of these vegetative propagation techniques and the training programme is recommended.

1. INTRODUCTION

Many dipterocarp species are economically important for their hardwood timber. The timber of these trees makes up about 25 percent of the total global tropical hardwood timber trade (Smits, 1987). Many dipterocarps (e.g. *Shorea javanica)* also yield other products, such as resin for the production of varnishes and turpentine. Fruits of several dipterocarps, called tengkawang, contain fat that is used in chocolate and the cosmetic industries (Sidiyasa, 1995).

The exploitation of the dipterocarp forests by logging operations however, has caused a sharp decrease in this resource. There is therefore a need to conserve, regenerate, protect and properly manage dipterocarp forest to ensure the sustainability of these forests. Planting activities for forest rehabilitation and reforestation need a continuous supply of plant material. Enrichment planting using dipterocarp species offers good economic prospects and is ecologically appropriate. Plant material normally used in these activities may originate from natural regeneration such as seeds, seedlings, wildlings and/or from vegetative propagation, like the stem cutting system. Whatever the source of the planting stock, its continuous supply is of the utmost importance to forest tree planting activities.

Since 1987 the International MoFEC-Tropenbos Kalimantan project, Wanariset Samboja, developed a technology for the vegetative propagation of dipterocarp species by means of stem cuttings that may meet the need for a continuous supply of planting stock. As a pioneer of this method, Wanariset Samboja is continuously searching for ways to improve the system. This paper discusses the research results of vegetative propagation and the introduction of the technology to concession holders and other forest institutions through training courses at Wanariset. The system is now well known and widely applied throughout Indonesia.

2. SELECTION OF PRIORITY SPECIES

The family of the Dipterocarpaceae is a very big family, consisting of 16 genera in 3 subfamilies making up about 515 species (Jacobs, 1981; Yasman et al., 1994). In the natural forests dipterocarps may comprise up to 80 percent of the trees in the upper canopy. Dipterocarp trees have long straight boles of large diameters, have rather homogenous timber of good quality and occur in large numbers. The timber of the Dipterocarpaceae has become a very important source of raw material from the forest. In addition, most of the species float on water, which makes the transport costs relatively low.

There is large variation in growth among the dipterocarps. Some species are very slow growing (e.g. *S. laevis*), while others can reach an average annual diameter increment of more than two centimetres (e.g. *S. leprosula*). It is therefore important to select the species with a specific growth rate. Provenance and progeny are also important criteria within the same species. Other decisive factors on which to base the choice of specific species are the site requirements, such as the suitability of the species for the local altitude, climate, soil type etc. Apart from the economic value, that has been mentioned already, there is the social acceptability (Smits, 1995). Poor species site matching will lead to poor growth and, therefore, economic loss. Poorly growing trees are also susceptible to pests and diseases.

The research group of the Wanariset Samboja selected 20 priority dipterocarp species for research and development based upon these criteria. The list of these species is given below in Table 1.

Table 1 Priority list of Dipterocarps species in Wanariset Samboja

No.	Dipterocarps species	No.	Dipterocarps species
1.	*Shorea pauciflora*	11.	*Shorea pachyphylla*
2.	*Shorea parvifolia*	12.	*Shorea dasyphylla*
3.	*Shorea leprous*	13.	*Shorea selanica*
4.	*Shorea seminis*	14.	*Shorea platyclados*
5.	*Shorea johorensis*	15.	*Shorea albida*
6.	*Shorea smithiana*	16.	*Dryobalanops lanceolata*
7.	*Shorea ovalis*	17.	*Dryobalanops aromatica*
8.	*Shorea stenoptera*	18.	*Dryobalanops keithii*
9.	*Shorea polyandra*	19.	*Anisoptera costata*
10.	*Shorea macrophylla*	20.	*Anisoptera marginata*

Unfortunately, the tree selection programmes have not been as effective as they might have been because of lack of access to, or poor use of, species information. Too often, rehabilitation in the field followed trends and did not anticipate on future needs that were identified with vision and were based on wide insight as to what is available and suitable (Smits, 1995).

3. DIPTEROCARP PLANTING STOCK PRODUCTION

Several techniques are employed for the production of dipterocarp planting stock (Figure 1).

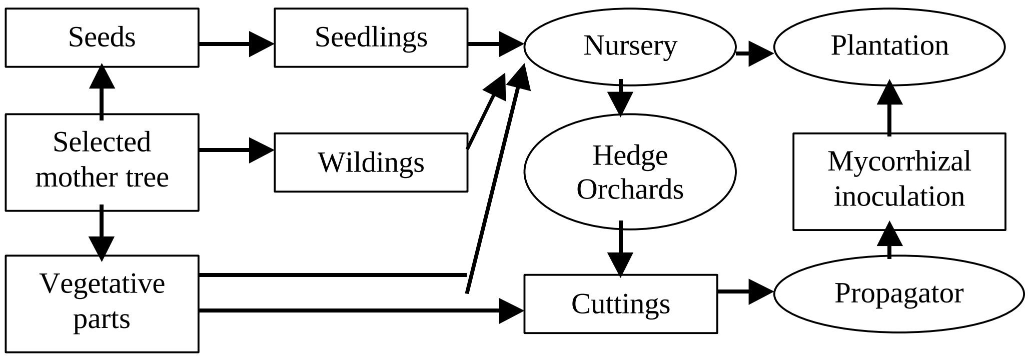

Figure 1 Dipterocarp planting stock production scheme

3.1 Seedlings

The production of dipterocarp planting stock through the controlled germination of seeds in nurseries is seldom practised. Seeds of species of the Dipterocarp family are produced in large quantities in periods of mass flowering once every 3 or 4 years. These periods are short, irregular and unpredictable. The seeds have a short viability period, a few weeks at the most, and are difficult to store (recalcitrant seed). In addition, insects and other animals eat many of the seeds. Accordingly, continuity of dipterocarp planting stock production originating from seeds cannot be guaranteed. Some research on seed technology has been conducted at Wanariset Samboja and has been published (Priadjati & Rayan, 1998).

3.2 Wildlings

A widely used method for the production of dipterocarp planting stock is by means of wildlings, collected underneath mother trees in the natural forest. In order to provide well identified wildlings, an area of high quality forest containing many commercial dipterocarps should be selected as a seed stand. It is also possible to collect the wildlings elsewhere, but the quality has to be taken into account.

Some important rules should be considered in the collection of dipterocarp wildlings. The collection should be done when the soil is very wet in order to reduce root damage. The species identification of young wildlings is difficult and only healthy and straight plants should be collected. The main problem in wildling collection is the condition during transport. If the wildlings are packed tightly and humid enough, the survival rate in the nursery is more than 95%, even for transport lasting up to one week (Smits and Leppe, 1991). High air humidity around the wildlings in the nursery is another important requirement. The technique for wildling production has been described in various publications (Giono *et al.*; 1996; Kusdadi and Priadjati, 1998; Leppe, 1995b) and in a simple manual (Smits, 1986).

Although very low in costs and technically simple to implement, the production of wildlings may still pose a problem if the aim is to obtain sufficiently large numbers of certain faster growing dipterocarp species. This is especially the case when natural mortality has significantly reduced the number of wildlings, as occurs two or more years after germination. Another consideration may be the need to select superior quality planting stock.

3.3 Vegetative propagation

Another method of dipterocarp planting stock production is by means of vegetative propagation. Vegetative propagating dipterocarps can provide an uninterrupted supply of high quality planting stock at times when wildlings may be scarce because of the time lapse since the last mass flowering. The techniques for vegetative propagation have long been considered as expensive, both in terms of investment as well as production costs. This was based on the high skills required for the production of cuttings and the treatment and handling of the cuttings in the nursery for rooting. Special technical provisions in the nursery and special biochemicals and fertilizers increased the costs. Moreover, the rooted cuttings needed to be inoculated with suitable mycorrhizal fungi in the nursery during the transplanting process.

4. WANARISET DIPTEROCARP PROPAGATION

As we stated above, vegetative propagation combined with mycorrhizae research started at the Wanariset Research Station in Samboja near Balikpapan as long ago as 1987. The MoFEC Tropenbos Kalimantan moved into the station in November of that year and started its programme of propagation and mycorrhizae research as its main activity. In a personal communication, Smits, the long-term team leader of the project, reports that vegetative parts of adult trees were tested in Wanariset Samboja using direct cuttings, air layering, grafting, spheroblastic shoots, with the results varying from complete failure to fairly positive. Direct cuttings from adult trees were tried for *S. lamellata, S. laevis, S. leprosula, S. ovalis, S. smithiana, S. seminis, S. pauciflora, S. parvifolia, S. johorensis and Dryobalanops lanceolata*. Pruning of adult trees followed by collecting cuttings from the sprouts had negative results, but subsequent grafting resulted in some success. Pruning of young dipterocarp trees (diameter less than 10 cm) followed by taking stem cuttings from shoots had a positive result. Other research by Omon (1997) on stumps of *S. balangeran* with 5 mm root collar diameter, combined with 15 mg Rotoone F showed a 97 percent survival rate.

The technique developed at the International MoFEC Tropenbos Kalimantan project involves rooting orthotropic stem cuttings of juvenile dipterocarps with auxine hormone in both solid or water media. The water medium is aerated by means of a small air compressor as normally used in aquaria. The air humidity is kept high during the rooting process and the light intensity is somewhat reduced. The method of cutting production has been described in various publications (Leppe, 1995a; Smits *et al*, 1990) and in a manual by Yasman and Smits (1988).

Some studies have indicated that plants yielding faster rooted cuttings also grow faster. There are some differences in root system development when cuttings are rooted in water or in a solid medium such as washed river sand or vermiculite. In water, fewer roots tend to develop and they become much longer and less branched, as compared with roots of cuttings in a solid medium (Tolkamp and Priadjati, 1996). The overall survival of rooted cuttings from a solid medium is slightly higher than that of cuttings rooted in water. Rooting percentages do differ slightly between the two methods, depending upon the species considered. Some species developed roots faster in water (e.g., *Hopea rudiformis, S. ovalis*), others faster in sand (e.g., *S. lamellata*) or vermiculite (e.g. *Dryobalanops lanceolata, S. smithiana, S. parvifolia, S. pauciflora, S. seminis*) and *S. leprosula* in both water and vermiculite media (Tolkamp and Priadjati, 1996). Another difference between rooting in water and in a solid medium is the number of roots developed from lenticels and those from wound calluses. Some species, like *D. lanceolata,* develop more roots from lenticels in water. Other species, like *S. ovalis,* develop more roots from lenticels in sands. Again other species, like *S. leprosula,* show no differences.

Table 2 The internal and external factors influenced the rooting ability of cuttings

Internal factor (cutting)	**External factor (propagator)**
Species	Humidity
Age/Juvenility	Light intensity
Hormone	Temperature
Physiological condition	Media
Resting period	Fertilization
Provenance	Day length
Technique	Aeration

There is large variation in rooting ability amongst the provenances within one dipterocarp species. *D. lanceolata*, originating from Longnah, East Kalimantan, had a lower rooting percentage compared with the same species originating from Wanariset Samboja, East Kalimantan. *S. smithiana* originating from Longnah, East Kalimantan, had a higher rooting percentage compared with the same species originating from Wanariset Samboja, East Kalimantan (Leppe and Juliaty, 1996). During the many years of research, a number of factors have been identified that influenced the rooting ability of dipterocarp cuttings. The main internal and external factors are listed in Table 2.

The development of a hedge orchard is needed to provide a sufficient regular supply of cutting material. The method for the establishment and maintenance of hedge orchards is described in various publications (Tolkamp and Priadjati, 1997a), in a detailed manual by Leppe and Smits (1989) and in a simple manual by Leppe (1995c). Experience has shown that, the older the age of a hedge orchard, the higher the production of cuttings, but these cuttings have a lower rooting ability.

The rooting ability of a cutting is also influenced by the maintenance of hedge orchard (Tolkamp, 1995). It is important to discover the optimal age of a hedge orchard for each individual species. The pruning of hedge orchards can produce juvenile shoots and stimulate the higher rooting ability of cuttings from these shoots (Macdonald, 1976; Hartmann, *et al* 1990; Tolkamp, 1995). The older the source material, the higher the concentration of externally applied auxine needed, but there are no absolute concentrations of hormone needed, because the rooting of cuttings is influenced by many factors (Table 2). The highest rooting percentage for species grown in Longnah, East Kalimantan, was obtained from shoots taken from two year-old hedge orchard. The rooting percentage of the cuttings from a four year-old, well-maintained hedge orchard, can still be high (Bachtaruddin *et al*, 1994). Cuttings obtained from trees older than 10 years did not root successfully. A detailed overview of the rooting ability of 20 important timber species is given in Table 3.

The success of the method, from the moment the cutting is made until a rooted cutting is ready to be planted in the field, varies between species, but is about 60-70% on average. This figure is the overall result of different success percentages. Cutting survival and successful rooting in the greenhouse is 80%. Conditioning after transplanting in the nursery beds shows a survival rate of 95%, while the same figure of 95 % is recorded for survival in the further nursing period until the plantlets leave the nursery (Bachtaruddin *et al* 1994).

Smits (1994) describes nursery aspects of mycorrhizae in detail, whereas Noor (1995) describes them briefly. The method for mycorrhizal inoculation has also been described in various other publications (Omon, 1999; Yasman, 1995).

Table 3 Overview of rooting ability of dipterocarp cuttings

No	Species	Hormone		Media	Period (weeks)	Rooting ability (%)	Hedge Orchard (age)	References
		Type	Conc. (time)					
1	*Anisoptera marginata*	IBA	10^{-4} (1 h.)	Peat:Sand (1:1)	5-9	100		Smits (1987)
2	*Cotylelobium spp.*	Rootone F	20 g/300 ml (20 minutes)	Water	16	0		Tolkamp & Priadjati (1996)
3	*Dipterocarpus cornutus*	Rootone F	20 g/300 ml (20 minutes)	Water	21	33		Tolkamp & Priadjati (1996)
4	*Dryobalanops lanceolata*	Rootone F	20 g/300 ml (20 minutes)	Vermiculite	16	69		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	67	3 years old	Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	43	6 years old	Tolkamp (1997)
		Without			21	17	3 years old	Priadjati & Prayitno (1998)
5	*S. assamicca*	Rootone F	20 g/300 ml (20 minutes)	Water	21	93		Tolkamp & Priadjati (1996)
6	*S. faguetiana*	Rootone F	20 g/300 ml (20 minutes)	Water	19	5		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	0	3 years old	Tolkamp (1995)
7	*S. johorensis*	Rootone F	20 g/300 ml (20 minutes)	Water	18	25		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	10	3 years old	Tolkamp (1995)
		Rootone F	100000 ppm (20 minutes)		21	21	3 years old	Priadjati & Prayitno (1998)
		Rootone F	Dipping	Vermiculite	48	0	6 years old	Tolkamp (1997)
8	*S. lamellata*	Without		Sand	4	90	8 months old	Omon & Smits (1989)
		IBA	200 ppm (1 hour)	Sand	4	100	8 months old	Omon & Smits (1989)
9	*S. leprous*	Rootone F	20 g/300 ml (20 minutes) & Dipping	Water & Vermiculite	11-26	51-75		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	32		Tolkamp (1995)
		Rotoone F	15 g/300 ml (20 minutes)	Water	22	50		Priadjati (1995)
		Rootone F	Dipping	Vermiculite	48	61	6 years old	Tolkamp (1997)
		Without			21	21	3 years old	Priadjati & Prayitno (1998)
		Without		Vermiculite	14	63	1 year old, wounding	Tolkamp & Priadjati (1997b)
10	*S. ovalis*	Rootone F	30 g/300 ml (20 minutes)	Water	21-26	63		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	17	3 years old	Tolkamp (1995)
		Without			21	31	3 years old	Priadjati & Prayitno (1998)
11	*S. parvifolia*	Rootone F	Dipping	Vermiculite	11-29	48		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	15		Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	0	6 years old	Tolkamp (1997)

No	Species	Hormone		Media	Period (weeks)	Rooting ability (%)	Hedge Orchard (age)	References
		Type	Conc. (time)					
12	*S. pauciflora*	Rootone F	Dipping	Vermiculite	20-29	59		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	17		Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	55	6 years old	Tolkamp (1997)
13	*S. selanica*	Rootone F	30 g/300 ml (20 minutes)	Water	16	67		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	20	3 years old	Tolkamp (1995)
14	*S. seminis*	Rootone F	Dipping	Vermiculite	19-29	78		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	64	3 years old	Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	45	6 years old	Tolkamp (1997)
		IBA	100 mg/l (24 hours)	Water	72 days	27-34	Wounding	Erwinsyah (1994)
15	*S. smithiana*	Rootone F	20 g/300 ml (20 minutes)	Vermiculite	17	21		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	11	3 years old	Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	0	6 years old	Tolkamp (1997)
						100		Smits (1987)
16	*S. stenoptera*	Rootone F	20 g/300 ml (20 minutes)	Water	26	0		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	0	3 years old	Tolkamp (1995)
17	*S. laevis*					100		Smits (1987)
18	*S. blanco*					100		Smits (1987)
19	*Shorea spp.*	Rootone F	100000 ppm (20 minutes)		21	61	3 years old	Priadjati & Prayitno (1998)
1	*Diospyros borneensis*	Atonik	20 ppm (5 minutes)	Water	3-7 months	60-93		Omon (1997)

5. PRACTICAL ASPECTS

The most commonly heard concerns about the risks associated with vegetative propagation are the risks of pests and diseases caused by genetic narrowing of the trees produced, poor root architecture and poor wood quality. No serious pests and diseases problems associated with large dipterocarps have been experienced so far. Some species even showed the presence of insecticides and fungicides in their resins (Messer, 1991). From root observations of both naturally grown and plantation grown trees, it has become clear that trees grown from cuttings developed a root system similar to that of natural regeneration (Bachtaruddin *et.al.*, 1994; Smits, 1995). Studies on the wood anatomy of some very fast grown individual dipterocarp trees have shown that, although the wood is lighter and somewhat less strong and durable (Bosman, 1992), it is still within the natural variation of the species and within the product specifications used in the markets. Moreover, no signs of problems such as brittle heart and cell collapse were encountered. These facts indicate therefore that the vegetatively propagated trees of the Dipterocarpaceae family present no problems of product quality and they do offer very favorable economic prospects in terms of growth.

Vegetative propagation techniques have been developed both to enable dipterocarps to be used for large-scale production and to make these techniques more cost efficient. The choice between wildling or cutting production, in terms of economics of production, depends on the time lapse between the last dipterocarp mass flowering and the time the planting stock is needed. The cost of wildling production increases exponentially with time, while the cost of cutting production increases more slowly in time. The cost comparison model, a software program developed for cost comparisons in nursery and stand establishment operations, can assist in deciding when it becomes more advantageous to produce wildlings and when it is better to produce cuttings. For the most common situation, at a certain point in time after the occurrence of the last mass flowering, the production cost of one cutting becomes less than that of one wildling.

Training courses on propagation through stem cuttings have been given in Wanariset Samboja since 1993. There have so far been more than three hundred participants from concession holders, forestry institutions and also from mining companies. The Wanariset dipterocarp propagation method was first applied on a production scale by PT Inhutani I in Longnah, East Kalimantan, where a nursery was established capable of producing more than half a million cuttings per year (Bachtaruddin et.al. 1994). In 1994, a total of 328 forest concession holders in Indonesia had already established hedge orchards to support the vegetative propagation of dipterocarps (Leppe and Smits, 1996).

6. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions which can be drawn from the propagation research are:
- The Wanariset research has resulted in the development of a successful rooting and mycorrhizal inoculation technology making possible the efficient production of planting stock for forest rehabilitation and reforestation with dipterocarp species, independent of the availability of seeds and wildlings.
- The vegetative propagation of dipterocarps through stem cuttings, as developed at the Wanariset Research Station, is feasible and generally accepted and applied by forest concession holders throughout Indonesia

In order to improve the propagation technology and contribute further to the conservation, rehabilitation and sustainable management of the dipterocarp forest in Indonesia we recommend:
- further integrated research, including genetic improvement
- increased research input; in terms of both personnel and resources
- updated manuals
- evaluation, updating and increase in training courses
- monitoring of participants of training courses
- monitoring the introduction and application of the technology in the forestry sector
- improved co-operation between institutions

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REHABILITATION OF WANARISET SECONDARY FOREST (EAST KALIMANTAN) THROUGH DIPTEROCARP SPECIES LINE PLANTINGS

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ABSTRACT

As a result of unsustainable management and wild fires, Indonesia is covered by over 20 million hectares of degraded forests. These heavily disturbed forests need to be rehabilitated. The International MOFEC Tropenbos Kalimantan Project recognised this problem and started a Dipterocarpaceae research programme in 1987, focussing on mycorrhizae, vegetative propagation and planting stock production, selection of species, soil and site classification, growth and yield studies and economics. This paper briefly discusses the different research efforts related to the production of planting stock, the rehabilitation of *Imperata cylindrica* grasslands and enrichment plantings in secondary forest. The research setting is described by giving some details of forest history, the characteristics of the area and the impact of fires. The fires of 1997-1998 essentially destroyed all field experiments.

Results of experiments and observations with Dipterocarp species in enrichment line plantings in the Wanariset Research Forest (East Kalimantan) during the years 1989–1999 are summarised. Species choices, planting stock production, planting establishment and maintenance are discussed. First year results of the establishment of 170 ha line plantings in burnt secondary forest are presented. On the basis of those results, future research is proposed and suggestions are made of how to proceed.

INTRODUCTION

The 1982-1983 drought and fires in East Kalimantan affected ca. 3.5 million hectares of land. Lennertz and Panzer (1984) estimated that 0.8 million ha of the total area was primary rainforest, 1.4 million ha logged-over forest, and 0.55 million ha peat swamp biome. The wild fires of 1997-1998 affected 3.2 million hectares in the Mahakan basin of East Kalimantan, of which 2.7 million ha were tropical (secondary) rainforest (Goldammer et al., 1999). All field experiments established before 1998 at the Wanariset Research Station were destroyed by these fires. Only 50 ha in the primary forest area could be saved.

This degraded forest land coverage will increase further through forest exploitation activities, shifting cultivation and mining. Other causes of forest degradation and forest conversion include transmigration, oil palm establishment and other forms of land use. In the 1970s the Indonesian deforestation rate was estimated at 300,000 ha/year. In 1981 to the figure was 600,000 ha/year and it rose again to 1,000,000 ha/year in the 1990s (World Bank in Sunderline et al., 1996).

The rehabilitation of heavily disturbed forest through natural regeneration is a process of many, many years. Active rehabilitation practices are needed to restore original functions of the forest within a reasonable period. To obtain successful results, appropriate rehabilitation methods were sought through research cooperation, both nationally and internationally. The combined

Ministry of Forestry and Estate Crops (MOFEC) and Tropenbos Foundation Project is one such piece of research cooperation that started in 1987.

The International MOFEC – Tropenbos Kalimantan Project recognised the rapidly growing problem of degraded forest that had to be rehabilitated, and developed a research programme for forest restoration. The central theme of the research programme for many years was the growth of indigenous Dipterocarpaceae species. The research focussed on mycorrhizae, vegetative propagation and planting stock production, species selection, soil and site classification, growth and yield studies and economics. Methods for collecting wildlings of Dipterocarp species, production of stem cuttings and hedge orchards were developed through this co-operation between Indonesia and the Netherlands and adopted by the forestry sector. For large-scale rehabilitation programmes, seedling production through a combination of the available production methods (seedlings, wildlings and stem cuttings seems to be the most appropriate strategy (Adjers and Otsamo, 1996). Vegetative propagation of Dipterocarp species, especially stem cuttings production, has given promising results and is used for large-scale plantations, for instance, Meranti (*Shorea* spp.) plantations with stem cuttings in Long Nah, East Kalimantan. (Bachtaruddin et. al., 1994).

Degraded forest can broadly be grouped into three main categories. The first category is lightly degraded forest still containing the main characteristics of the original forest. Natural regeneration restores the original forest within a reasonable time. Light exploitation or light fire damage has created this category and this forest is not considered for rehabilitation. Medium to heavily disturbed forest created by logging and forest fire or combinations of the two is the second category and is the subject of this presentation. The vegetation consists of trees and shrubs of the original forest or of pioneer species. This secondary forest can be rehabilitated by enrichment plantings in lines or in other spatial arrangements. The third main category includes *Imperata cylindrica* (alang-alang) grasslands. These are open areas resulting from complete depletion of forest cover and repeated and frequent burning. Alang-alang grass with some herbs and smaller shrubs are the main vegetation elements. Other speakers in this workshop will discuss rehabilitation of this category. Tolkamp et al. will present "An ecologically based strategy for the reforestation of *Imperata cylindrica* grasslands in East Kalimantan" and Murniati will describe her PhD research "Conversion of Imperata grassland into an agroforestry system by application of mycorrhiza and shading by trees".

First, the research setting, that is, the location of the research station and the experimental forest, will be described., The forest fires in 1997-1998, which practically burned down the whole research forest and destroyed all the experimental plantings, will be briefly discussed. In the main body of this paper there follows a description of enrichment planting experiments and their results, both published and unpublished. The paper ends with the conclusions of the authors.

RESEARCH SETTING

Location

The research reported on here is a common effort of Indonesian and Dutch researchers working together in the International Ministry of Forestry and Estate Crops-Tropenbos Kalimantan Project. The project's offices and research facilities are part of the Wanariset Samboja Research Station, which is located 38 km from Balikpapan in East Kalimantan. The Wanariset Samboja Research Station is a satellite of the Samarinda Forest Research Institute, one of the research institutes of the Forest Research and Development Agency of the Ministry of Forestry.

East Kalimantan is an Indonesian Province on the island of Borneo, part of the Indo-Malayan tropical rainforest region. The climate of the region is classified as humid tropical rainforest climate with a northwest "wet" monsoon (November-April) and a southeast "dry" monsoon (May-October), and a total annual rainfall of about 2400 mm (Schmidt and Ferguson, 1951). The original vegetation of East Kalimantan ranges from mangrove and swamp forest to montane forest. By far the largest forest type is lowland rainforest, dominated by species of the Dipterocarpaceae family. Very large parts of the original forest have been logged, burned and converted to other forms of land use. The coastal region of East Kalimantan is now a mosaic-like landscape, consisting of a very few small patches of original rainforest, all varieties of logged and burnt forests, alang-alang grasslands, forest plantations and industrial estates, shifting cultivation areas and permanent smallholding agriculture. Apart from forest products, the province is rich in oil, natural gas, coal and gold.

Wanariset Research Forest

The Wanariset Samboja Research Forest is located next to the Wanariset Research Station. Initially, the Ministry of Forestry designated only 504 ha of forest land to the research station to serve as experimental forest. This forest consisted partly of primary forest and partly of logged-over forest. The research forest was surrounded by extended logged-over forest, which suffered from forest fires in 1983. An additional 3000 ha were added to the research forest in 1992, making the total area of research forest 3504 ha. At the same time, it became part of the Bukit Suharto Protection Forest. In 1997-1998 almost the whole of the research forest was burnt. Only about 50 ha of primary forest was saved from the fire, a small patch of original forest in which the “Wartono Kadri” trail has been laid out.

The 3504 ha of research forests consisted originally mainly of dry land dipterocarp forest and patches of swamp forest at an altitude of 50 – 150 m above sea level. Meteorological measurements between 1994 and 1998 at the nursery of Wanariset Samboja showed an annual rainfall ranging from 1135 mm to 2631 mm and a number of rain days ranging from 81 to 150 days per annum. An average daytime temperature of 29-32 °C and a humidity of 56-96 % were further measured. The terrain of the forests is flat, undulating, rolling and hilly with swampy depressions. The soil is alluvial and derived from Upper Miocene sedimentary rock (LPT, 1964). On the basis of soil surveys, Iriansyah et. al (1998) describe the soil in the flat areas as typical tropaquepts and humic tropaquepts, in the undulating to almost flat areas as aquic hapludults and in the rolling to hilly areas as typical hapludults, typical paleudults and typical dystropepts.

Original vegetation

The composition of the original forest before logging and fire damage is very well known, thanks to a detailed study by Kartawinato et al. (1981) of the vegetation in a plot in the Wanariset research forest. The vegetation in this forest, identified and measured in a 1.6 ha plot, consisted of 239 species, belonging to 122 genera and 45 families, which was the richest forest stand so far in the country. The Dipterocarpaceae family comprised 14 species: *Dipterocarpus cornutus, D. gracilis, Shorea gibbosa, S. laevis, S. lamellata, S. leprosula, S. ovalis, S. palembanica, S. parvifolia, S. pauciflora, S. smithiana, Shorea spp., Vatica umbonata, and Vatica spp*. The ten most common families were Euphorbiaceae (26 species), Dipterocarpaceae (14 species), Lauraceae (14 species), Sapotaceae (12 species), Myristicaceae (12 species), Burseraceae (11 species), Meliaceae (13 species), Annonaceae (8 species), Moraceae (8 species) and Rubiaceae (8 species). The density of trees with diameter at breast height (dbh) of 10 cm and above was 541 trees/ha. 90 Dipterocarp trees had a total basal area of 16.4 m^2. Pioneer species found in secondary forests included: *Macaranga spp. Mallotus spp, Bamboo, Octomeles spp. Neonauclea spp* and *Trea orientalis.*

PLANT PRODUCTION AND STAND ESTABLISHMENT RESEARCH

Plant production

Several techniques are employed for the production of planting stock of dipterocarp. They include: seedling production in nurseries from seeds, wildlings collected in the forest and seedlings derived from cuttings raised in the nursery. The research results of vegetative propagation of dipterocarps are presented in the paper of Priadjatis et al. "Vegetative propagation to assure a continuous supply of plant material for forest rehabilitation" (in these proceedings). The paper also describes the introduction of this technology to concession holders and other forest institutions through training courses at Wanariset. The system is now well known and widely applied throughout Indonesia.

Imperata cylindrica

An ecologically-based strategy to accelerate the reforestation of grassland towards a dipterocarp-dominated plantation, in which natural regeneration occurs, has been developed in combination with fire control measures. Tolkamp presents in his paper (in these proceedings) the first step in the implementation of this strategy: "The establishment of a pioneer plantation, which started in 1996". The results so far indicate that essential prerequisites for success are the selection of both pioneer and dipterocarp species and the use of appropriate fertilisers. *Peronema canescens* seems to be a suitable species for the first phase of grassland reforestation in Indonesia and the domestication of this species has been started. The paper suggests feasibility studies and a comprehensive programme of more integrated research (experiments performed by concessionaires, mining companies and farmers, but supervised by researchers). Table 1 gives an overview of the 14 experiments in *Imperata cylindrica* grasslands.

Table 1 Overview of experiments in *Imperata cylindrica* grasslands

No.	Name of the experiment	Size/ ha	Location	Established	Number species	Results reported	Current status
1	Pioneer species selection in *Imperata cylindrica* grasslands (I)	1.5	Inhutani	1996	40	Tolkamp et al., 1998; Tolkamp, 1999	Burned
2	Pioneer species selection in *Imperata cylindrica* grasslands (II)	1.5	Inhutani	1996	40	Tolkamp et al., 1998; Tolkamp, 1999	Burned
3	The effect of initial fertilisation with NPK and five slow release fertilisers on growth performance of four pioneer species	0.3	Inhutani	1996	4	Tolkamp et al., 1998; Tolkamp, 1999	Burned
4	Selection of 12 dipterocarp spec. in *I. cylindrica* grassland.	1.5	Inhutani	1995	12	Tolkamp et al., 1998; Tolkamp, 1999	Burned
5	Elimination trial involving 9 local and 5 exotic tree species for grassland rehabilitation	0.8	WRF	1998	14	No	Ongoing
6	Pioneer species trial on I. cylindrica grassland	0.6	WRF	1998	5	No	Ongoing
7	Collecting *Peronema canescens'* cuttings of 12 origins (provenances) and 50 clones		WRF	1998	1	Tolkamp, unpublished	Ongoing
8	The influence of storage duration on the rooting ability of *P. canescens* cuttings		WRF	1998	1	Riskan & Rayan, unpublished	Finished
9	The influence of the origin of cuttings on the rooting ability of *P. canescens.*		WRF	1998	1	Tolkamp & Alkadafi, unpublished	Finished
10	Direct planting of unrooted and rooted *P. canescens* cuttings *in I. cylindrica* Dominated grasslands	0.3	WRF	1999	1	Tolkamp & Taupik, unpublished	Ongoing
11	Shading effect of *P. canescens* on the initial Growth of *S. leprosula* cuttings	0.2	Inhutani	1998	2	PhD- study	Ongoing
12	*P. canescens* hedge orchard of several origins	0.2	WRF	1999	1	No	Ongoing
13	Agroforesty plantation	2	WRF	1998	4	Tolkamp, unpublished	Ongoing
14	Fire breaks of *P. canescens*	4	WRF	1999	1	Tolkamp, unpublished	Ongoing

*WRF = Wanariset Research Forest

Enrichment plantings in secondary forest

Research on the rehabilitation of secondary forest by enrichment planting started at the Wanariset Research Station in 1989, when the first demonstration plot of 200 ha was established with the co-operation of Inhutani I. In the same year, another trial with 8 dipterocarp species, originating from cuttings, was set up. From 1989-1993, research activities were concentrated on the study of mycorrhizae associations and on vegetative propagation. In this period very little research was conducted on actual forest rehabilitation. From 1993, new activities were started and, in the period 1993-1996, nine new trials were established in secondary forest. The general objectives of these experiments were to select, propagate and establish indigenous tree species for the rehabilitation of secondary forest. The great forest fire of 1997-1998 destroyed all the trials (see next chapter) before the results of a number of experiments could be recorded. After the fire new trials for experiments with enrichment planting were re-established.

An overview of the 16 experiments in secondary forest is given in Table 2, and the results are published in scientific papers, proceedings, Wanariset Technical Reports or are to be found in unpublished documents. The experiments are discussed in the chapter on "Enrichment planting experiments".

Table 2 Overview of enrichment experiments in secondary forest

No.	Name of the experiments	Size/ Ha	Location	Established	No. of species	Results reported	Current status
1	Bare-rooted planting of *Hopea nervosa* Wildlings	0.5	WRF*	1988	1	Yasman, Giono and Smits, 1993	Burned
2	Planting of *Hopea nervosa* wildlings in heavily, moderately and lightly burnt forest	1	WRF	1988	1	Leppe, 1993	Burned
3	Effect of gap opening in burnt forest	0.5	WRF	1988	3	Massofian Noor and Leppe, 1995	Burned
4	Demonstration plot for dipterocarp enrichment line plantings	200	Inhutani	1989		No	Burned
5	Species comparison of 8 dipterocarp species from cuttings	2	Inhutani	1989	8	No	Burned
6	Dipterocarp species progeny experiment	3.7	WRF	1993	?	No	Burned
7	Survival rate and growth comparison between cuttings and wildlings of 7 dipterocarp species	1.5	ITTO **	1993	7	Priadjati et al., 1999	Burned
8	Fertilisation of *Shorea leprosula* cuttings in Line plantings	1.5	WRF	1995	1	Tolkamp, 1996	Burned
9	Selection of 12 dipterocarp species in secondary forest.	1.5	WRF	1995	12	Tolkamp et al.,1998; Tolkamp, 1999	Burned
10	Survival rate and growth comparison between cuttings, wildlings and seedlings of 9 dipterocarp species	2	Inhutani	1996	9	Priadjati et al., 1999	Burned
11	Selection of 10 dipterocarp species planted in secondary forest in the Inhutani concession	2	Inhutani	1996	10	Mulyana, 1999	Burned
12	Selection of 10 dipterocarp species planted in secondary forest in the ITTO forest area.	2	ITTO *	1996	10	No	Burned
13	Planting methods of *Shorea balangeran*	0.3	WRF**	1996	1	No	Burned
14	Influence of the width of line cleaning on survival and growth of 10 dipterocarp species in the Wanariset Research Forest	5.0	WRF	1998	10	No	Ongoing
15	Influence of the width of line cleaning on survival And growth of 10 dipterocarp species in Sebulu	5.0	Sebulu	1998	10	No	Ongoing
16	Rehabilitation of 154 ha secondary forest through Dipterocarp line plantings	154	WRF	1998-1999	27	N0	Ongoing

*WRF = Wanariset Research Forest. **ITTO = ITTO forest rehabilitation area.

IMPACT OF FOREST FIRES

Before the Wanariset Research Forest was established, most of the area was logged. This logged-over forest suffered from the great forest fires of 1983, except for a small area of 504 ha directly adjacent to the Wanariset Research Station. All the current research forest of 3505 ha burnt down again in 1997-1998, except for 50 ha in the primary forest area where the trail called “Wartono Kadri” had been laid out. Because of the fire and drought no fruit bodies of mycorrhiza spp. could be found, forcing PhD researchers (Mulyana and Aldrianto) to reschedule their PhD-studies, as inoculation experiments could not be carried out. Several areas containing transects for phenological observations were burnt down.

The experiments that were burnt down are indicated in Tables 1 and 2. In many cases, field experiments established to test tree provenance or progenies and to compare growth of different species over long periods of time were destroyed. The financial losses are hard to quantify. It is to be questioned whether such experiments should be restarted when no adequate fire protection can be assured. Most of the experiments on forest rehabilitation were relatively new and hardly any conclusions could have been drawn from them. Another serious problem is that the burnt area of the Wanariset research forest is prone to serious human encroachment. A revised strategic plan for the Wanariset Research Forest must be developed to overcome the problems of fire and human encroachment.

ENRICHMENT PLANTING EXPERIMENTS

Bare rooted planting of *Hopea nervosa* wildlings (Yasman, Giono and W.T.M. Smits, 1993)
The objectives of this experiment were to compare survival rate and growth performance of wildlings planted in different planting holes and with and without the protection of plastic covers. Bare root *Hopea nervosa* wildlings with 2-5 leaves, were taken from natural regeneration following the instructions given in the "Technical Guidance for Dipterocarp Wildlings System" (Smits, 1990). The collected wildlings were put in plastic basket, assuring high humidity during transportation to the planting holes in a planting site about 2 km away. Four treatments were applied: planting without cover in (1) big holes and in (2) small holes and planting with plastic cover in (3) big holes and in (4) small holes. The wildlings were planted in lines about one metre wide that had been cleared of vegetation. The distance between the lines was 3 m and the distance between holes was also 3 m. Vegetation in the plantation area consisted of burnt forest with some big trees and an abundance of pioneer species such as *Macaranga gigantea, M. triloba and Mallotus spp*. The undergrowth plants were *Maranta,* climbing bamboo, fern and grasses and herbs. The light intensity that reached the forest floor was about 50 %. The overall result of the experiment showed a reasonably high survival rate of 58.6 %. The survival rates of the four treatments were 70%, 63%, 49% and 53%, respectively. Wildlings planted under *Macaranga gigantea* had a higher mortality. The use of plastic cover in the experiment had a negative effect especially during periods of continuous rain. The falling water hit the cover, causing the plastic to stick to the plants. The wildlings without a plastic cover showed a higher survival rate compared with wildlings with a plastic cover. It was concluded that bare rooted planting could be done for enrichment planting in belukar (secondary shrub forest). The required conditions are to plant in the rainy season with enough precipitation to give a high soil and air humidity and to plant under a vegetation cover that reduces light intensity to 50-75 %.

Planting of *Hopea nervosa* wildlings in heavily, moderately and lightly burnt forest (Leppe, 1993)
Leppe (1993) studied the influence of the nursing period in the nursery on the survival and early growth of *Hopea nervosa* wildlings planted in different types of burnt forest in 1987. The experimental design used was Randomised Complete Block Design with three replications. The three treatments applied in the nursery were one, two and three months of nursing and the different site conditions consisted of heavily, moderately and lightly burnt forest.

The research results after 48 months of observations showed that the survival rate of one month maintenance in the nursery (71%) was slightly higher compared to two and three months' maintenance rates of 67% and 54%, respectively. On the basis of forest condition, planting under heavily burned forest gave a higher survival rate (74 %), compared to moderately (64 %) and lightly burnt (54 %). The mean annual diameter increment was 0.16 cm and the mean annual height growth was 22 cm.

The study concluded that *Hopea nervosa* wildlings that are 12 cm high when collected in the forest need only one month's maintenance in the nursery. *H. nervosa* is considered a slow growing species, comparable with *Shorea laevis*. It was also concluded that this species could be planted in rather open areas or between shrubs.

Effect of gap opening in burnt forest (Noor and Leppe, 1995)

The effect of light intensity on the survival and growth of tree species by creating different sizes of opening in the vegetation cover was studied over nine years. The study was carried out in burned forest in the Wanariset Research Forest. A factorial experiment in a randomised block design was applied. The A factor included tree species: *Shorea parvifolia, S. ovalis* and *S. smithiana,* while the B factors were light intensities of 30-50 % and 50-70 %, respectively.

The result of the experiment showed that, nine years after planting, the average heights of *S. parvifolia, S. ovalis* and *S. smithiana* were 6.44, 5.62 and 7.96 m, respectively. Their average diameters were 4.71, 3.57 and 7.80 cm, respectively. The effect of gap opening giving a light intensity of 50-70% in the beginning showed the fastest growth and the highest survival rate for the three species was achieved with a gap opening of 30-50 % light intensity.

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Survival rate and growth comparison between cuttings and wildlings of seven dipterocarp species planted in 1993 (Priadjati and Tolkamp, unpublished)

In December 1993 an experimental plot was established to study the survival rate and growth performance of cuttings and seedlings of seven dipterocarp species. The plot was located in a secondary forest dominated by *Macaranga*. A randomised complete block design was used for this experiment. The cuttings used for planting were 9 months old and had a size of 30 cm or less. The wildlings were 2 years old with a size of about 80 cm. The cuttings and seedlings were planted at two different spacings, 5x3 m and 5x5 m. Survival rate, health index, height and diameter growth were measured after growing periods of 16 and 36 months, respectively. Table 3 gives an overview of the survival rate and height increment after 16 and 36 months, respectively.

Table 3 Mean survival rate (%) of cuttings and wildlings and mean height increment (cm) of mixture of both cuttings and wildlings of 7 dipterocarp species, 16 and 36 months after planting

Species	**Survival (%)**		**Height increment ((cm)**	
	36 months		**16 months**	**36 months**
	Cuttings	**Wildlings**	**2 origins**	**2 origins**
Shorea parvifolia	26	58	130 a	307 a
Shorea leprosula	71	77	128 a	227 a
Shorea smithiana	58	71	107 ab	255 ab
Shorea pauciflora	60	81	78 b	180 bc
Shorea ovalis	51	79	70 c	150 cd
Shorea seminis	48	94	67 c	116 d
Dryobalanops lanceolata	73	67	98 abc	236 abc

*Values followed by the different characteristics in the same column are significant at 5%.

The number of measured plants decreased in the course of time due to mortality and broken tops. At the end of the 36 months growing period, the mean survival rate of cuttings and wildlings was 53% and 71%, respectively. The mean survival rate differed per species and varied from 26% (*S. parvifolia* cuttings) to 94% (*S. seminis wildlings*). *Dryobalanops lanceolata* and *S. leprosula* showed the highest survival rate for cuttings, respectively 73% and 71%, while the survival rate for the wildlings was 67% and 77%, respectively. *Shorea parvifolia* showed the lowest survival rate of all 7 species, 26% for its cuttings and 58% for its wildlings.

The height of the individual trees within the species varied enormously, from less than 1 metre to more than 8 metres (*S. smithiana*, *S. leprosula* and *S. parvifolia*). Differences in height increment between species occurred after a growth period of respectively 16 and 36 months (Table 3). The fastest growing species were *S. parvifolia, S. leprosula* and *S. smithiana*, with an average height increment of 307, 277 and 255 cm, respectively, after 36 months growth. *S. seminis* and *S. ovalis* showed the lowest height increment, 116 and 150 cm, respectively.

Differences in height increment emerged between cuttings and wildlings after growth periods of 16 and 36 months, respectively. For 6 species, the growth of wildlings was faster than the growth of cuttings, with the exception of *D. lanceolata*. This species demonstrated an average increment in 36 months of 269 cm for cuttings and 199 cm for wildlings.

The reasons for these interesting differences within the species and between the cuttings and wildlings could not be evaluated, because of the impact of the fire in August 1997. Indicators are the differences within the plot, such as the planting stock quality of cuttings and wildlings, the topography, soil, light intensity and competition.

Survival rate and growth comparison between cuttings, wildlings and seedlings of nine dipterocarp species planted in 1996 (Priadjati and Tolkamp, unpublished)

In June 1996 a similar experiment to that described under 5.1.4 was started to compare the mortality and growth performance of different dipterocarp species and of different production origins. Cuttings, wildlings and seedlings of nine dipterocarp species were planted in open secondary forest dominated by *Vernonia arborea*. Six of the species used were the same as in the 1993 experiment. The same experiment lay-out and planting distances (5x3m and 5x5m) were used. The reason for this similar set-up was to eliminate the heterogeneity of the 1993 experiment. Table 4 gives details of the survival rate and height increment 12 months after planting.

Table 4 Mean survival rate (%) and mean height increment (cm) of 9 dipterocarp species produced from cuttings, wildlings and seedlings, 12 months after planting

Species	**Survival (%)**			**Height increment (cm)**		
	Cuttings	**Wildlings**	**Seedlings**	**Cuttings**	**Wildlings**	**Seedlings**
Shorea parvifolia	83	81		24	30	32
Shorea leprosula	83	86		40 b	59 a	
Shorea pauciflora	86	78	81	25	26	17
Shorea ovalis	83	86	86	26	24	22
Shorea seminis	78	89		14 b	27 a	
Shorea laevis		86	92		22 b	34 a
Shorea parvistipulata		67	69		13 b	21 a
Dipterocarpus cornutus		61 b	97 a		9 b	18 a
Dryobalanops lanceolata	81	83		33 a	21 b	

*Values followed by the different characteristics in the same row are significantly different at 5%.

Twelve months after planting the dipterocarp line planting showed a survival rate of 81% from a total of 792 plants. The species with the highest and lowest survival rates were *S. laevis* (93%) and *S. parvistipulata* (69%), respectively. No differences were found between the three production origins except for *D. cornutus*. Seedlings from this species showed a higher survival rate (97%) than its wildlings (61%). The height and diameter increment was the same for cuttings, wildlings and seedlings of the species. However, differences occurred between the production origins in most of the tested species, as is shown in Table 4.

Preliminary results suggest that the initial plant condition at planting time is a major factor for successful enrichment planting. This emphasises the importance of obtaining high quality planting stock from the nursery. Differences in growth between and within the same species became apparent. A tailor-made solution must be developed in each case, depending on the local conditions, species and available level of technology. In large-scale operations, a combination of planting seedlings, wildlings and cuttings is likely to be most appropriate.

Application of fertiliser to *Shorea leprosula* cuttings in line plantings (Tolkamp, unpublished).

Slow growth of Dipterocarps in line plantings hampers the introduction of this rehabilitation method for the degraded secondary forests in Indonesia. The major reasons are the absence of ectomycorrhizal fungi and nutrients in the soil and the lack of optimal light conditions. It was hypothesised that trees planted with slow release fertilisers will grow faster than trees to which no fertiliser has been applied or trees treated with NPK fertiliser. A second hypothesis is that slow release fertilisers are not harmful for the development of ectomycorrhizal fungi (Termorshuizen, 1993; Julich, 1988).

To study the effect of slow release fertilisers and of NPK dressing on the survival rate, early growth and ectomycorrhizal development of cuttings planted in line plantings, an experiment was designed using a complete randomised block design with 49 tree plots replicated 4 times per fertiliser treatment. Four fertilisers were compared with the control: the slow release fertilisers Osmocote 10+26+10+5 (30 gr), Osmocote 17+9+8+4 (30 gr), Rock phosphate (25 gr) and NPK 15+15+15 (100 gr).

The experimental plot was established in 1995 in logged-over, burnt (1983) forest. The secondary forest area was dominated by approximately 12-year old *Macaranga* spp. and there was no natural regeneration of Dipterocarps. Light intensity regulation by different thinnings of overtopping trees was not applied. *S. leprosula* cuttings (with an average height of 38 cm) were planted in the lines at a distance of 3x5 m. All the one-year-old cuttings were infected in the nursery with ectomycorrhizal fungi, mainly with *Amanita* species, but some of them with a combination of *Riessiella spp.* (named amphimycorrhizae by Smits, 1994) and *Amanita spp.* (Tolkamp, 1996). The fertilisers were applied directly in the planting hole, with the exception of NPK, which was broadcast around the base of the stem, just one month after planting. Results were analysed with the two-way ANOVA, 4 and 10 months after planting. Dead and damaged plants were excluded from the analysis.

The average survival rate was low at 60%. This was due to mechanical damage, by the method of NPK application and by wildlife damage. Big *Macaranga gigantea* leaves and broken branches of these trees damaged 26% of the *S. leprosula* plants. The high mortality of the plants treated with NPK (72%) was probably caused by applying the fertiliser too close to the stem or by too high a dose of NPK. Of the plants to which no fertiliser had been applied and those treated with rock phosphate showed an acceptable survival rate (80% and 70%, respectively).

The average height increment of 32 cm after 10 months did not differ between the different fertiliser applications. The mean height increment of *S. leprosula* cuttings of 32 cm after 10 months was disappointing. However, the application of NPK and Osmocote 17+9+8+4 resulted in diameter increments of 42 mm and32 mm respectively, compared with the control of 20 mm.

The effect of the slow release fertilisers on growth could not be demonstrated. Although it was not built in as a variable in the experiment, indications suggest that light intensity had a strong influence of on growth performance. It is believed that the interaction between light intensity, increased mycorrhizal presence and improved nutrient utilisation probably holds the key to a more efficient use of fertilisers. Interference by fire in 1997 destroyed the experiment and it was only possible to analyse mycorrhizal presence before planting and survival and growth in response to fertiliser treatments 4 and 10 months after planting. It is too early for any conclusions. It is recommended that new research be conducted on this subject.

Dipterocarp species selection

A. The selection of dipterocarp species planted in secondary forest and in grasslands (Tolkamp, 1998 and 1999)

Two experiments on the selection of the most appropriate dipterocarp species were established in 1995 under different light conditions: one under a canopy of residual forest and one on open *I. cylindrica* grassland (Table 1). The first two years' results were published by Tolkamp in 1998 and 1999. These results are summarised in the article "Towards an ecology-based strategy for the reforestation of *Imperata cylindrica* grasslands in East Kalimantan" in these proceedings.

B. Selection of ten dipterocarp species in secondary forest in the Inhutani concession: results of the first year (Omon, 1999)

Ten dipterocarp species were tested using a complete randomised block design with 5 x 5 m spacing. These ten species, originating from wildlings, were *Shorea leprosula, S. selanica, S. ovalis, S. seminis, S. multiflora, S. teysmaniana, S. balangeran, Dryobalanops oblongifolia, Hopea odorata and H. mengarawan*. The wildlings came from Bogor in West Java, from Central Kalimantan and from Samboja East Kalimantan. The wildlings were inoculated with ectomycorrhizae using top soil (0-10 cm deep), taken from soil underneath dipterocarp mother trees in the Wanariset Samboja research forest. The wildlings were planted in secondary, burned (1982) forest dominated by *Piper aduncum* (sirih-sirihan). Lines were established 5 m apart, with one metre wide clearings and a spacing of 5m in the line. The result after 12 months showed that the survival rate varied from 80 % to 98 %. *Hopea odorata and H. mengarawan* showed the best survival rates, 98 % and 97 %, respectively. After 12 months, the average height growth varied between 21 – 43 cm and the average diameter growth (3-5 cm above the ground) was between 0.2 – 0.4 cm. To stimulate growth, it is recommended that shading trees should be eliminated by girdling or poisoning with "Roundup" (Omon Mulyana, 1999).

Experiments without reported results

A. Demonstration plot for dipterocarp enrichment line plantings, established in 1989

From 1989 – 1994 growth data were collected annually in large numbers, but never analysed.

B. Species comparison of 8 dipterocarp species from cuttings

In 1989 an experimental plot of 2 ha enrichment planting was established in the Inhutani I concession near the Wanariset Research Station. Cuttings of 8 different dipterocarp species were planted. Recorded data have not been processed and analysed.

C. Dipterocarp species progeny experiment

The experiment was established in 1993. Data were collected and are available, but have not yet been analysed. Reason: low priority for analysing data, because of the regular human encroachment and the fires in the area of the experiment.

D. The selection of ten dipterocarp species planted in secondary forest in the ITTO forest area

This experiment is a replication of the experiment presented, which was planted in another secondary forest area with different soil conditions. Results have not been analysed and published.

E. Planting methods of Shorea balangeran

A small experimental plot of 0.3 ha was established in the Wanariset Research Forest in 1996 to compare planting methods of *Shorea balangeran*. The plot burnt down and the initial data have not been worked out.

F. Effect of the width of line cleaning on the survival and growth of 10 dipterocarp species in the Wanariset Research Forest

This experiment was established in 1998 after the catastrophic wild fires of 1997/98. The width of cleaned lines in the burned Wanariset forest were: 1.0, 1.5 and 2.0 metres. Ten species were planted: *Shorea leprosula, S. smithiana, S. johorensis, S. pauciflora, S. balangeran, S. multiflora, S. gratissima, S. pinanga, Hopea mangarawan* and *Dryobalanops lanceolat*.

A wholly randomised block design was used, with 3 replications of 30 plant per species each. The survival rate was 40 - 85% one year after establishment. Mean height varied between 30 – 75 cm.

G. Influence of the width of line cleaning on survival and growth of 10 dipterocarp species in Sebulu

The set-up of this experiment in the Sebulu area is the same as that described under F, but with a few other species: *Shorea leprosula, S. smithiana, S. lamellata, S. ovalis, S. seminis, S. johorensis, S. stenoptera, S. pauciflora, S. balangeran* and *S. parvifolia.*

H. Rehabilitation of 154 ha of secondary forest using dipterocarp line plantings

In 1997 a co-operative project was started between PT Kelian Equatorial Mining (PT KEM) and Wanariset Samboja. The project aimed at the rehabilitation of an area of 500 ha of secondary forest and *Imperata cylindrica* grassland, located in the Wanariset research forest. Up to September 1999, approximately 154 ha of secondary forest had been planted. The tree species, most of them belonging to the Dipterocarpaceae family, planted were: *Shorea leprosula, S. johorensis, S. fallak, S. guiso, S. lamellata, S. laevis, S. macroptera, S. mojongensis, S. multiflora, S. ovalis, S. pauciflora, S. palembanica, S. parvifolia, S. potoinensis, S. selanica, S. seminis, S. smithiana, S. stenoptera, Dryobalanops lanceolata, Dipterocarpus convertus, D. tempehes, Hopea dryobalanoides, H. gigeria, H. mangarawan, H. odorata, Vatica sumatranadan V. oblongifolia.*

The planting material of dipterocarp species originated mainly from wildlings and a small amount from cuttings. These plants were produced in the nursery of Wanariset Samboja. Most of the wildlings were collected in the forests in East Kalimantan. Plantation was carried out in line plantings, cleared one metre wide, with lines 5 m apart and planting distance in the line of 5 m.. Initial recorded data has not yet been analysed and reported.

CONCLUSIONS

The survival rates of four bare-rooted treatments were 69.6 %, 62.7 %, 48.9 % and 53.2%, respectively. The use of plastic cover in the experiment had a negative effect, especially on continuous rainy days. The falling water hit the cover, causing the plastic stick to the plants. Treatments without cover produced a greater survival rate. Bare-rooted planting could be done for enrichment planting in shrubs or bushes. The required conditions were planting during sufficient rainfall, with the wildlings not subjected to full light intensity and a light intensity of 50-75 %.

The research results from *Hopea nervosa* wildlings of a height of 12 cm when pulled from the forest showed that one month maintenance treatment was the best. After 48 months of observations, the survival rate of one month's maintenance in the nursery (70.67 %) was found to be higher compared with that of two and three months, namely 67.33 and 54.00 %, respectively. On the basis of forest conditions, planting under heavily burned forest (block 3) gave the higher survival rate (74 %) compared to moderate (64 %) and light (54 %) burning. The mean annual increment (MAI) was 0.16 cm for diameter and 22 cm for height.

Gap opening study results showed that the average height nine years after planting *of S. parvifolia, S. ovalis* and *S. smithiana* was 6.44, 5.62 and 7.96 m, respectively. Their average diameters were 4.71, 3.57 and 7.80 cm, respectively. The effect of gap opening on the development and growth of the three species was significant. A light intensity of 50-70 % (57 %) had the greatest effect compared to 30-50 % (41.44 %) light intensity.

The results from 3.5-year old seven dipterocarp species line planting in *Macaranga*-dominated secondary forest originating from cuttings and wildlings showed that the mean survival rates of cuttings and wildlings were 53% and 71%, respectively. Mean survival varied from 26% (*S. parvifolia* cuttings) to 94% (*S. seminis* wildlings). *Dryobalanops lanceolata* and *S. leprosula* showed the highest survival for cuttings, of 73% and 71 % respectively , while the survival rates for wildlings were 67% and 77 %, respectively.

The result from 12-month old nine dipterocarp species line planting in a *Vernonia arborea*-dominated secondary forest originating from cuttings, wildlings and seedlings showed that the highest and lowest survival rates were for *S. laevis* (93%) and *S. parvistipulata* (69%). No differences were found for the three origins except for *D. cornutus*. Its seedlings showed a higher rate (97%) than its wildlings (61%). The height and diameter increments were the same for cuttings, wildlings and seedlings of the species.

Application of fertiliser to *Shorea leprosula* showed that the average survival rate of 60 % after ten months was caused by a high mortality (72%) of the plants treated with NPK and by game damage (pigs). The high mortality of NPK treatment was probably caused by either application too close to the stems or too high a dose. The survival rates of the plants not treated with fertiliser and plants treated with rock phosphate were 80% and 70%, respectively. Fertiliser application did not influence the average height increment of 32 cm after 10 months. However, the application of NPK and Osmocote 17+9+8+4 resulted in diameter increments of 42 mm and 32 mm, respectively, compared with the control (20 mm). The results were strongly influenced by external factors.

11. The survival rate after 12 months of ten Dipterocarps species planted using the line system in burned secondary forest dominated by *Piper aduncum* varied from 80.61% to 97.96%. *Hopea*

odorata and H. mengarawan had better survival rates (97.96% and 96.94%). The average height and diameter growth varied between 21.18 - 43.32 cm and 0.22 – 0.39 cm, respectively.

The impact of the 1997-1998 forest fires on the 3504 ha Wanariset research forest was very serious. All the research forest burnt down except for the 50 ha “Wartono Kadri” trail in the primary forest area. Field experiments to compare tree provenance or progenies, survival rates and growth performances of different tree species were destroyed. Transects for phenological observations were also burnt down. The duration of the experiment were relatively short and, consequently, hardly any sound conclusions can be drawn as a result of the catastrophic wildfires of 1997/1998. It is very important to have a fire prevention system prior to the establishment of field experiments.

RECOMMENDATIONS

- A forest research management plan should be drawn up, including fire management (prevention, early detection, fire fighting and aftercare) and participation by local people.
- No field experiments should be established without a properly functioning fire-management system and without the commitment of the local communities.
- Studies on species selection need to be continued and further developed.
- Species site-matching experiments should be continued and further developed.
- Silvicultural research in various forest types should continue and be renewed.

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MONITORING TROPICAL FORESTS USING SYNTHETIC APERTURE RADAR

Dirk H. Hoekman

ABSTRACT

Advanced Synthetic Aperture Radar (SAR) remote sensing systems, their versatility and applications for environmental monitoring and survey are briefly introduced. The results of experiments conducted at sites of the *Tropenbos* Foundation in Colombia and Indonesia are shown to illustrate their capabilities. These are: (1) A newly developed technique to derive 3D tree maps from airborne high-resolution interferometric radar images. (2) Land cover change and fire damage monitoring by the ERS SAR satellite. (3) Selection of appropriate radar system specifications for very accurate monitoring of deforestation, land and forest degradation, secondary regrowth and land cover change. The information needs for tropical forest areas are very diverse. The use of dedicated airborne radar systems in combination with aerial photography and operational satellite systems would provide a sound basis for efficient data acquisition in support of prudent future forest management.

I. INTRODUCTION

Remote sensing techniques are now widely used for environmental studies, surveys and monitoring. Among the wide variety of techniques, radar remote sensing is a relatively new one. As opposed to optical systems, it is characterised by its capability to make clear observations through clouds and, in the absence of solar illumination, it is an ideal instrument for monitoring, notably in humid tropical areas.

Tropical rainforests cover large parts of the Earth's land surface. The significance of these forests and the need for information, can be viewed from several perspectives: (a) Tropical rainforests play an essential role in global hydrological, biochemical and energy cycles and, thus, in the Earth's climate; (b) Tropical rainforests are among the Earth's most complex ecosystems and have a large biodiversity. The functioning of this ecosystem and the significance of its genetic resources are still not well understood; (c) Tropical rainforests are of great economic value as a major source of timber and other products, and as a source of land. Large areas have been converted into forest plantations, arable land and pastures. There is an urgent need for accurate data on the actual extent of the forest, on deforestation, forest structure and composition. These data are needed as input for climate studies, for the selection and monitoring of forest reserves (with or without sustainable use) and the monitoring of environmentally sensitive areas, the latter in relation to mining and selective logging activities in areas under sustainable management.

Radar remote sensing data may prove to be a unique means of meeting some of the major information needs. Many types of imaging radar systems have been developed during recent years, with different types matching different observation capabilities. In this paper we briefly introduce a selection of these systems (Sections 2 and 3) and the results of experiments conducted at *Tropenbos* Foundation sites in Colombia and Indonesia are shown to illustrate their capabilities (Sections 4, 5, and 6). The combined use of several spaceborne and airborne systems may appear to be the most appropriate for operational applications (Section 7). Section 8 concludes by evaluating the significance of radar in support of prudent forest management.

II. SAR SYSTEMS

Imaging radar systems map a strip of terrain by illuminating the terrain in the cross-track flight direction with short microwave pulses and recording their echoes. The principle is illustrated in Figure 1, in which a short pulse is transmitted within a fan-shaped beam illuminating an elongated area on the ground. The first echo arrives from the near range position of the illuminated spot or 'footprint'; the last echo from the far range of this footprint. The next pulse is transmitted a fraction *Dt* of time later and the echoes from the next footprint are subsequently recorded. The shape of this footprint is compressed through *aperture synthesis* to a small line, and sharp images, known as *Synthetic Aperture Radar* or *SAR* images, are created.

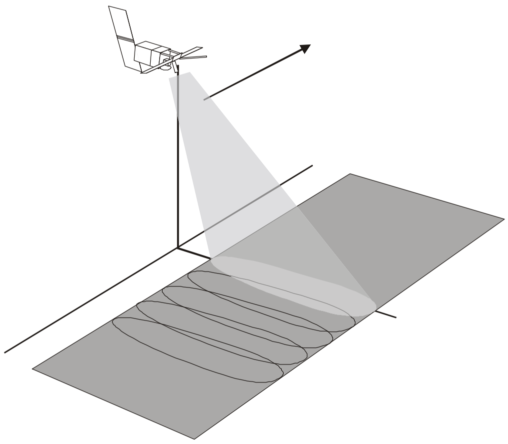

Figure 1 SAR mapping.

The bandwidth of a radar system is an important parameter for determining the sharpness or spatial resolution of the radar images. It is noted that, in contrast to optical images, SAR image resolution does not depend on the distance of observation. Another important parameter is the frequency band used for observation. These frequencies are letter-coded. A band with a high central frequency f_c, such as the C band ($f_c \approx 5.3$ GHz), will hardly penetrate the vegetation canopy.

Table 1 Dornier SAR sensor and image parameters [1)]. The use of this airborne system is discussed in Section 4.

Centre frequency	5.3 GHz
Bandwidth	100 MHz
Polarisation	VV
Incidence angle at mid-swath	63 degrees
Swath width	2 km
Number of looks	4
Operating altitude	3200 m
Range resolution	1.75 m
Azimuth res. (single look)	0.34 m
Slant range pixel spacing	1.25 m
Azimuth pixel spacing	1.36 m

[1)] One of the 6 modes selected for the 1996 deployment.

Low frequencies, on the other hand, such as those from the L-band ($f_c \approx 1.2$ GHz) and, notably, P-band ($f_c \approx 440$ MHz), can penetrate a completely closed vegetation canopy to a great depth and can also observe trunks and ground surface. By way of illustration, Tables 1, 2 and 3 list some of the major characteristics of the systems the use of which is discussed in this paper.

Table 2 ERS SAR sensor and image parameters. The use of this satellite system with a 35-day repeat cycle is discussed in Section 5.

Centre frequency	5.3 GHz
Bandwidth	15.5 MHz
Polarisation	VV
Incidence angle at mid-swath	23 degrees
Swath width	100 km
Number of looks	3
Operating altitude	782 km
Range resolution	<33 m
Azimuth resolution	<30 m
Ground range pixel spacing	12.5 m
Azimuth pixel spacing	12.5 m

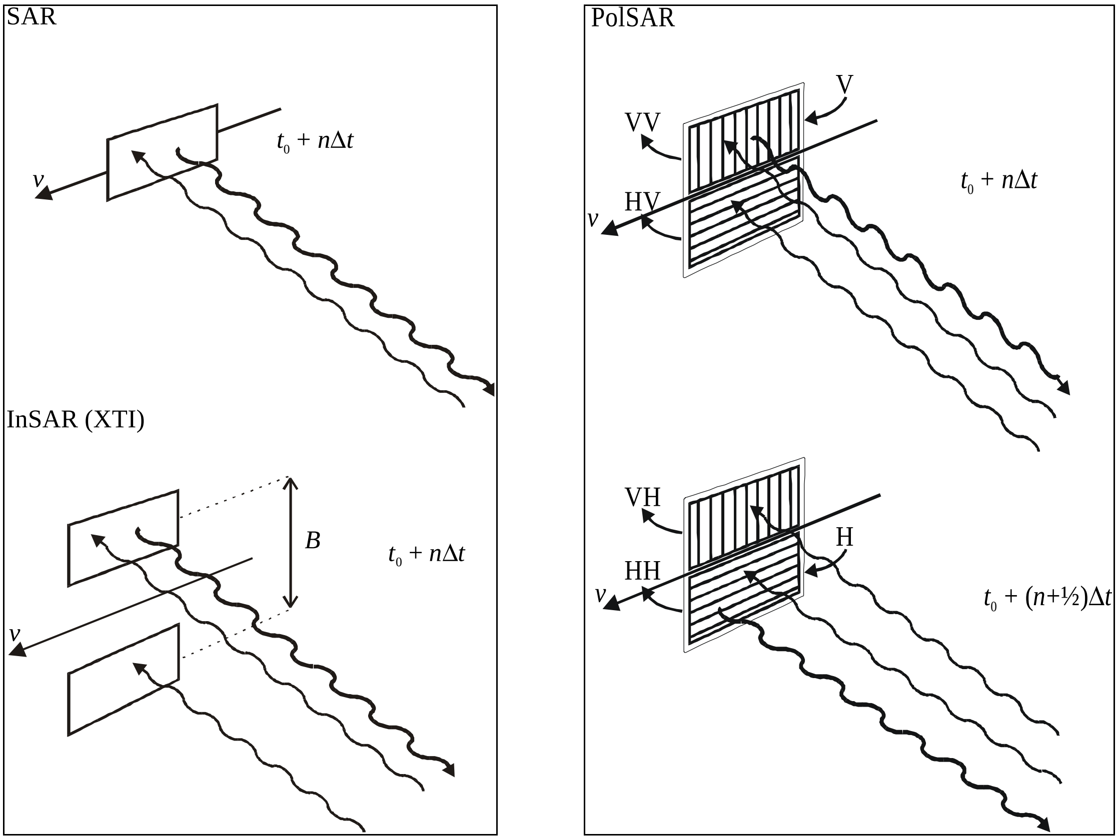

Figure 2 Antennae configurations of advanced SAR systems. The arrow indicates the flight direction. (Top left:) Conventional SAR with single antenna for transmission and reception. (Bottom left:) Interferometric (across-track) SAR with additional antenna for reception. (Right:) Polarimetric SAR with two polarised antennae for transmission (V and H) and reception VV, HV, VH and HH).

Radar systems can create more than one image at the same time. Multi-band systems, for example, create images using several frequency bands simultaneously. Advanced radar systems can even carry out more observations by using additional receiving antennas. In the rest of this section we will discuss very briefly some of the properties of such advanced systems, relevant for the interpretation of results presented in this paper. For a more detailed account the reader is referred to the handbook of Henderson and Lewis (1998).

Table 3 AirSAR sensor and image parameters [2)]. The use of this airborne system is discussed in Section 6

Centre frequencies	**5.3 GHz (C-band), 1.25 GHz (L-band) and 0.44 GHz (P-band)**
Bandwidth	20 MHz
Polarisation	Polarimetric
Incidence angle range	20-60 degrees
Swath width	10 km
Number of looks	16
Operating altitude	8000 m
Range resolution	10 m
Azimuth resolution	1 m
Slant range pixel spacing	6.7 m
Azimuth pixel spacing	8.3 m

[2)] Selected for the 1993 deployment. The current AirSAR system has more operating modes, including modes with higher resolution.

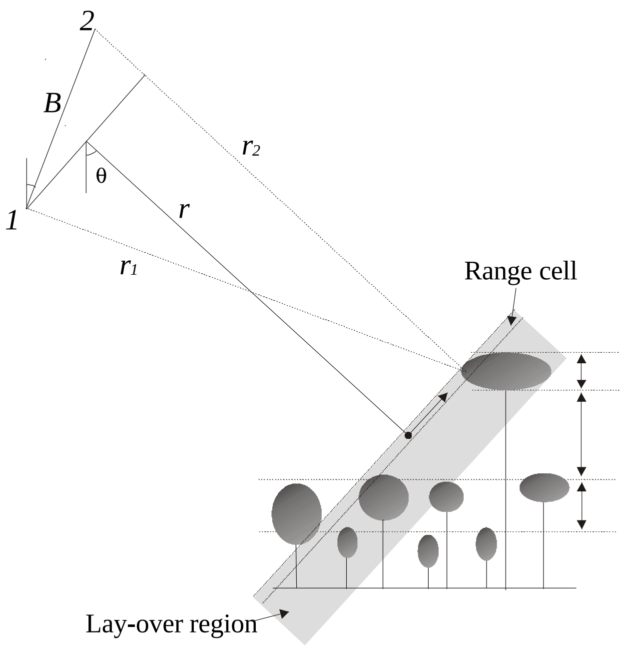

Figure 3 InSAR and lay-over. The antenna positions are numbered as 1 and 2 and are separated by the baseline distance *B*. The echo of the large tree is mixed with the echoes of smaller trees.

The conventional SAR system is diagrammatically depicted for purposes of comparison in Figure 2 (top left). Here an antenna transmits pulses with a time interval *Dt* and the same antenna records echoes in the period between transmissions. An *interferometric* SAR system uses an additional receiving antenna, separated by the *baseline* distance *B* (Figure 2, bottom left). Since the path the reflected pulse has to travel back to the transmitting antenna generally differs from the path the reflected pulse has to travel back to the non-transmitting antenna, a phase difference arises between the two radar echoes. Since this phase difference can be related to the direction of the echoes and the distance of the reflecting object can be computed from the time elapsed between transmission and reception of the pulse, the three-dimensional position of the reflecting object can be determined. In Section 4 this technique is used to create three-dimensional 'tree maps'. A problem arises when, for example, two trees (with different heights) are located at the same distance (Figure 3).

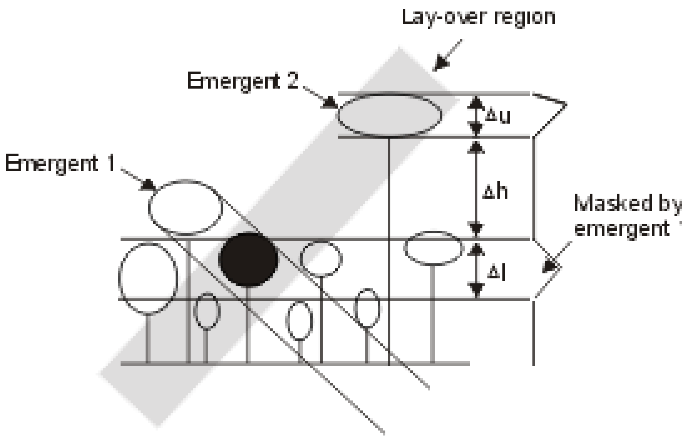

Figure 4 InSAR and shadowing. Compare with Figure 3. The echo of the large tree (emergent 2) is well-defined, because smaller trees at the same distance are in the 'radar shadow' of another large tree (emergent 1) and cannot interfere.

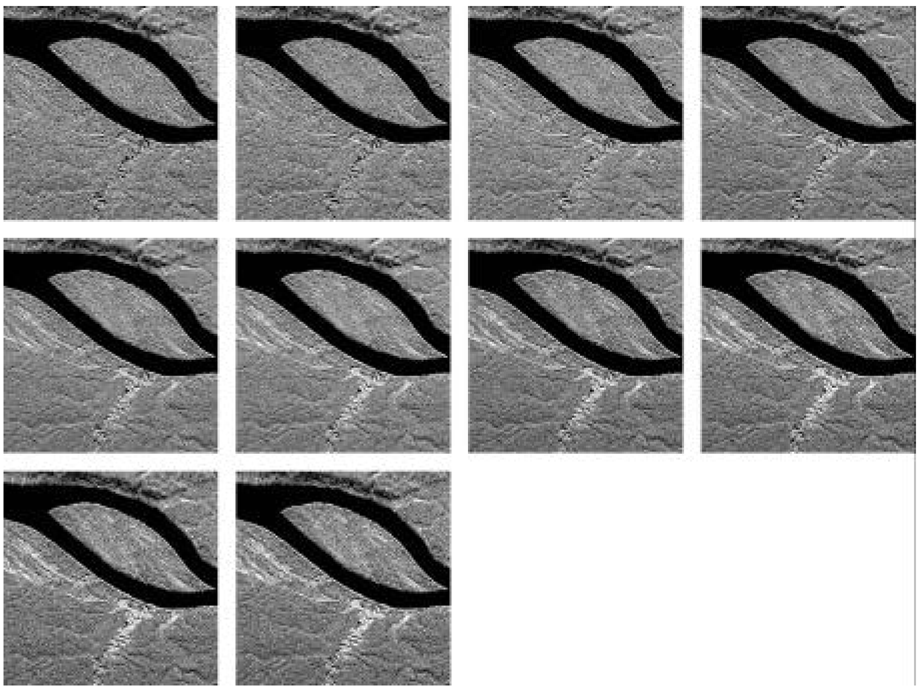

Figure 5 Polarisation synthesis shows the flood plain of the Rio Caquetá in Colombia for varying polarisation. In the first image a horizontal wave is used for transmission and a vertically polarised antenna is used for reception. The orientation of the plane of polarisation is changed in 9 steps of 5 degrees from 0 to 45 degrees for the transmitting wave and from 90 to 135 degrees for the polarisation of the receiving antenna. In the last image the contrast between flooded forest and non-flooded forest is maximised, while in the first image the contrast is completely absent.

Such a situation can be recognised, since the phase differences of these two trees are different and the mixing of their echoes results in a signal with a low *phase coherence*. The tree mapping technique discussed in Section 4 utilises this signal characteristic.

A *polarimetric* radar system is shown in Figure 2 (right). In this system, a vertically polarised wave is transmitted (the wave has a short duration and, depending on context, is sometimes called a pulse, as above). When a wave is reflected from an object it can change polarisation, and this change is measured by comparing the vertical polarised part of the reflection measured by the (transmitting) vertically polarised antenna with the horizontally polarised part of the reflection measured by a second, horizontally polarised, antenna. A horizontal polarised wave is next transmitted and, again, horizontally and vertically polarised parts of the reflected wave are measured. The vertically and horizontally transmitted waves are interleaved, resulting in four measurements of back scatter in the time interval *Dt*. Using *polarisation synthesis* it is possible to determine the back scatter properties of an object for any polarisation. An example is given in Figure 5, which shows a section of the floodplain of the Rio Caquetá in Colombia.

By combining these four measurements, a series of images can be created. In the first image a horizontal wave is used for transmission and a vertically polarised antenna is used for reception. The orientation of the plane of polarisation is changed in nine steps from 0 to 45 degrees for the transmitting wave and from 90 to 135 degrees for the polarisation of the receiving antenna. In the last image the contrast between flooded forest and non-flooded forest is maximised, while in the first image the contrast is completely absent. In general, a proper analysis of polarimetric data can reveal important information about forest structure.

III. APPLICATIONS OF SAR

SAR is a very versatile technique for environmental monitoring and survey. Its applications are diverse and include topics like rainfall mapping, bathymetry, monitoring of currents and wind at the ocean surface and monitoring of deformation of active volcanoes, (sub-canopy) flooding, soil moisture and vegetation. Its potential relevance for tropical rainforest mapping and inventory greatly depends on the type of radar and platform used. A tentative overview is given in Table 4.

Table 4 Generalised overview of information products and their possible relation to radar system types and user requirements.

SYSTEMS	**AIRBORNE**		**SATELLITE**	
Requirements	**High resolution & Short Wave**	**Long Wave**	**Short Wave**	**Long Wave**
Detailed Inventory	- tree maps - topography	-forest type -flooding conditions -(vegetation height)	-	-
Monitoring Indicators of Sustainable Management	- tree extraction - skid trails - reforestation	-land degradation -secondary regrowth	- illegal clear-cut detection - timber road network expansion	-land degradation -secondary regrowth
Fire Risk & Damage Assessment	- plant/soil moisture content - canopy closure	-	- plant/soil moisture content - loss of green biomass	-
Map Updating	*Scale 1:5,000-1:25,000*	-biomass classes -land cover change	- change detection - topography (*Scale 1:100,000*)	-biomass classes -land cover change

IV. TREE MAPPING

To study the potential of radar for tropical rainforest management, the Indonesian Radar Experiment (or INDREX-96 campaign) was conducted in Indonesia in 1996 under the auspices of the Indonesian Ministry of Forestry and the European Space Agency ESA (Wooding *et al.*, 1998). The Dornier SAR system (Faller and Meier, 1995) collected data in several modes over *Dipterocarp* rainforest test sites in the provinces of East-Kalimantan and Jambi. In this paper shows the results of high-resolution (1.5 m) C-band interferometric SAR data (one of the six modes tested, see also Table 1) for one of the East-Kalimantan test sites ('site A' located in the ITCI concession).

Parameters such as tree position, tree crown dimensions, canopy cover and terrain slope angle, and the location of skid trails and logging roads, are of particular interest for forest management. In principle, such information can be retrieved on a routine basis over large areas from aerial photographs. Repeated observation would allow assessment of logging intensity, erosion and fire susceptibility, verification of reforestation obligations, etc. However, cloud cover too often prevents regular observation.

Radar does not have this limitation. Moreover, images acquired by short-wave high-resolution radar, in principle, may give sufficient information for such applications. Since other physical mechanisms underlie radar imaging, radar images cannot be treated in the same way as aerial photographs. Allowance has to be made for the effects of 'radar shadow' and 'lay-over', in particular. Lay-over, for example, occurs where two tree crowns with different heights are located at the same range distance (Figures 3 and 4). In non-interferometric (i.e. conventional) radar images, these two tree crowns will be imaged on top of each other, without the interpreter being able to detect the fact. In interferometric images this situation can be detected through the measurement of *phase coherence*. In tropical forests height differences between individual trees can be substantial and are common. Emergent trees in primary and logged-over forests can reach more than 10 m above other upper canopy trees. The same is true of secondary forest, which often comprises remnants of the former primary forest. In theory, the problem of lay-over may be solved to a large extent by making use of the observed interferometric phase coherence. Loss of coherence is indicative of lay-over and can be modelled as a function of vegetation height differences. The greater the height differences in a certain range cell, the lower the observed coherence. In Hoekman and Varekamp (1998), the observed coherence found for such emergent trees is compared with predictions made using the Van Cittert-Zernike theorem. Results clearly show that the interferometrically derived height can be a substantial underestimate of the true tree height, while, at the same time, large displacement errors for individual trees may occur. Application of the Van Cittert-Zernike theorem can correct for both types of error and may be basic to the development of inversion algorithms for the automated production of tree maps.

Several approaches for tree mapping are currently being developed and tested. In one approach tree crown boundaries are fitted to the radar data by positioning a deformable template in such a way as to maximise the slope of the interferometric height at the boundary of the crown (Varekamp and Hoekman, 1999). An example is given in Figure 6, which shows a radar image sub-scene of part of a fully surveyed 7.2 ha area (Prakoso *et al.*, these proc.). In this figure the colours relate to interferometric height and intensity to radar back scatter intensity. The result of tree detection and boundary fitting is shown in Figure 6 (right) using Figure 6 (left) as a backdrop image. These results are subsequently transformed into a geometrically corrected map of tree crowns in orthographic projection (Figure 7). Each tree is labelled and parameters such as position, height, crown projected area, crown shape (resulting from boundary height and top height) and radar back scatter properties are listed for further information processing. A comparison with field data is made in the paper by Prakoso *et al.* (these proc.).

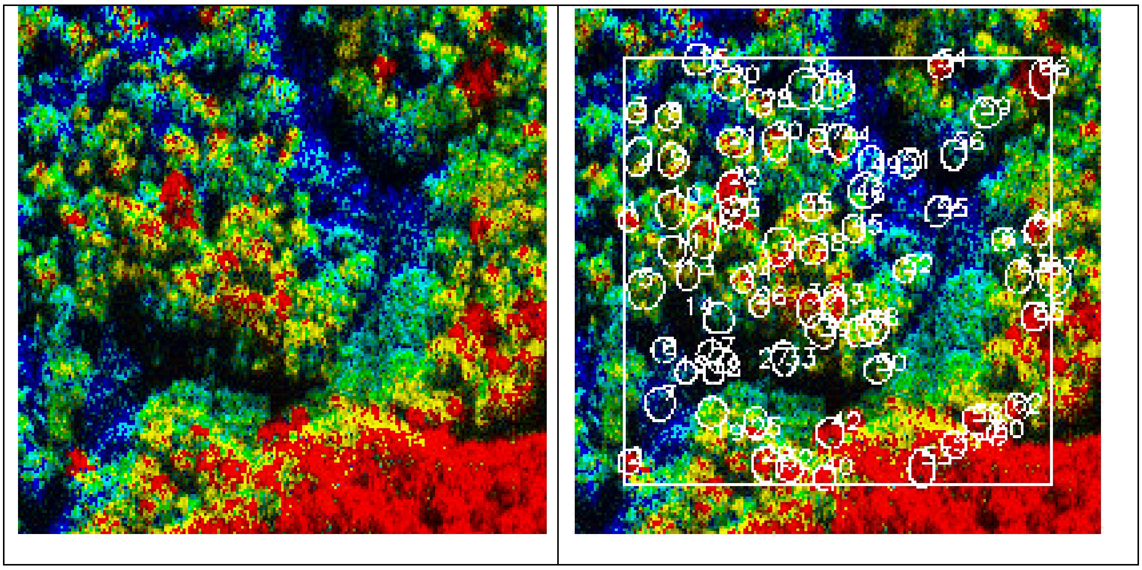

Figure 6 (In colour) DoSAR data and delineated tree crowns. The colour relates to the interferometric height and the intensity to radar back scatter intensity. The result of tree detection and boundary fitting is shown on the left, using the image on the right as a backdrop image.

Tree maps derived from radar data differ from tree maps made terrestrially, e.g. by the FIEPLP method (Smits, these proc.). Special features of interest for both types of product may be summarised as follows.

(1) Tree maps derived from radar data:
- In principle, can be made quickly, cheaply and for large areas.
- They accurately indicate positions of tree crowns, which can be used for referencing.
- They show *most* canopy trees.
- They show tree crown dimensions, which can be useful for determining the direction of tree felling in order to minimise damage.
- They can be used to select areas for fieldwork (e.g. to make FIEPLP tree maps).
- Moreover, when multi-temporal observations are made, radar image change detection can be applied very easily for detecting areas of unexpected change (illegal logging), and radar tree maps can be made for these selected areas. Note that this implies that it is not always necessary to produce radar tree maps in order to obtain results; this can speed up the process and reduces costs to a minimum.

(2) Tree maps derived from terrestrial surveying, such as FIEPLP tree maps:
- Show trunk diameters in excess of 20 cm, for *all* trees.
- Show species. (Radar may only give broad categories. This is the subject of further study.)
- Show terrain topography (while radar shows canopy topography).

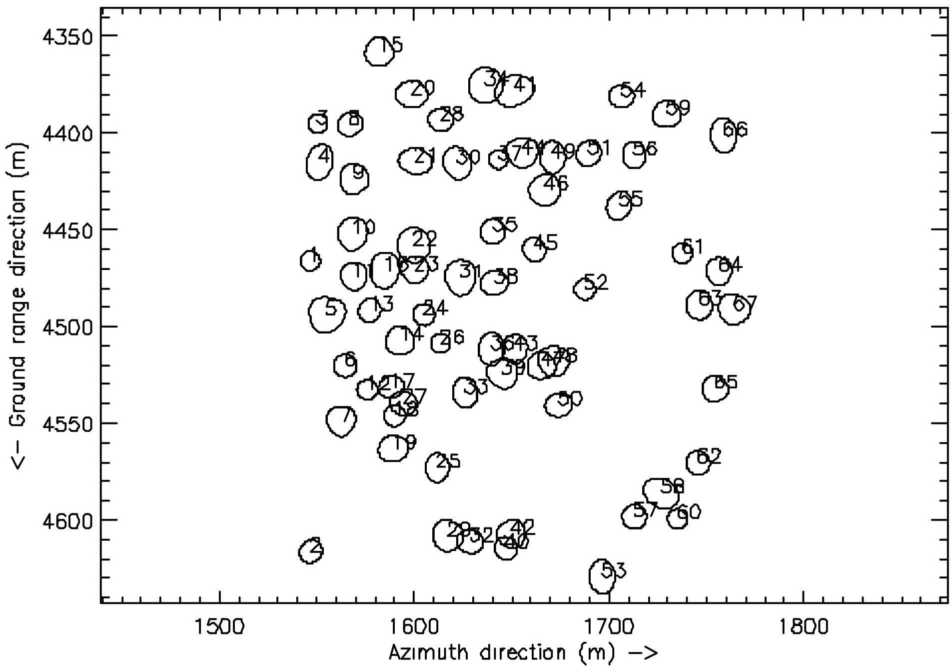

Figure 7 Radar tree map: A geometrically corrected map of tree crowns in orthographic projection.

These products are clearly complementary. Radar tree maps facilitate fieldwork for the production of FIEPLP tree maps and, at the same time, can give additional information. The real value of radar tree maps is that, in principle, they can be made quickly and cheaply for all the areas needed. They may give sufficient information for enforcing legislation for sustainable forest management. Where more detail is needed, more detailed information can be added by field surveys.

V. LAND COVER CHANGE AND FIRE DAMAGE MONITORING

A large number of ERS SAR scenes acquired of the East-Kalimantan *Tropenbos* test site in the period 1993-1996 have been studied in support of the Indonesian Radar Experiment (INDREX-96), with the objective of studying its potential for land cover change monitoring. Subsequently, an additional series of ERS SAR scenes was acquired in support of studies to assess fire damage caused by the severe El Niño event, which occurred at the same test site in the period June 1997 – April 1998.

ERS SAR data have been used previously in many land cover change monitoring studies, including the Guaviare *Tropenbos* site in Colombia and in Indonesia. The thesis by Bijker (1997) describes a monitoring system for Guaviare linking land cover change models and multi-temporal ERS SAR observations. Mapping accuracy in the order of 60-70% was obtained for forest, secondary vegetation, pastures and natural grasslands. The study by Kuntz and Siegert (1999) along the Mahakan river in the Indonesian province of East Kalimantan describes how several land cover types such as undisturbed *Dipterocarp* forest, heath forest, secondary forest, clear-cuts/shifting cultivation and selective logging can be mapped successfully using texture analysis and a time series of observations.

In general, optical systems like SPOT or Landsat-TM yield a higher accuracy than ERS SAR. For example, Trichon *et al*. (1999) show that high accuracy, i.e. in the order of 70-80%, can be obtained for mapping a large number of vegetation types in the Indonesian province of Jambi. However, cloud cover prevents optical systems from making the repetitive and frequent observation that is needed for monitoring. Statistics derived from the study of spatial and temporal distribution of cloud cover using geostationary meteorological satellites reveal that the probability of acquiring SPOT or Landsat-TM images with less than 30% cloud cover are definitely very low (Gastellu-Etchegorry, 1988a,b). For the Jambi test site, the mean probability of acquiring images with less than 70% cloud cover is only 26%.

The current study at the East-Kalimantan *Tropenbos* test site relates to land cover change and fire damage monitoring with the main emphasis on early detection. The terrain is very hilly and typical of the rugged topography encountered in most Indonesian forest areas. The modulating effects of slope angle and slope aspect on the back scatter intensity complicate the processing of data of hilly terrain. New multitemporal segmentation techniques (Oliver and Quegan, 1998) in combination with back scatter change classification techniques have been applied to deal with this problem.

Preliminary results show that areas affected by fire can be delineated well, but that it is sometimes hard to assess the intensity of the fire damage accurately. Combining ERS SAR observations during the fire period with land cover class information obtained by ERS SAR in the pre-fire period and observations of ‘hot spots’ (i.e. fires) by NOAA-AVHRR, together with knowledge of the types of fire occurring in this area, can be shown to yield very reliable results. An example of ERS SAR data and its classification is given in Figure 8. The result of an independent validation through fieldwork showed high accuracy for almost all land cover types, both before and after the fire period (Table 5). The result may seem poor for agricultural areas, but these areas comprise a mixture of gardens, rice fields, fruit tree plantations and forest remnants. Since agricultural areas are confused with plantations and forests, which also occur *within* the agricultural areas, the result may be much better when interpreted accordingly. Another result is that burnt forests are not always detected (85.2%). This is believed to be the result of ground fires, which leave the upper canopy largely intact for several months after the ground fire, so that the C-band SAR is unable to detect such a condition. It was also found that susceptibility to fire may be assessable by using the stability of the radar back scatter level in the pre-fire period as an indicator.

Table 5 Pre-fire and post-fire classification accuracy of multi-temporal ERS SAR data (shown in Figure 8).

Pre-fire		**Post-fire**	
Water	100%	water	100%
Mangrove	100%	mangrove	100%
Nipah	100%	nipah	100%
Swamp forest	Unknown	swamp forest	unknown
Forest	89.4%	non-burnt forest	98.8%
		burnt forest	85.2%
Plantation	88.5%	burnt plantation	98.4%
Agriculture	34.5%	burnt agriculture	28.5%

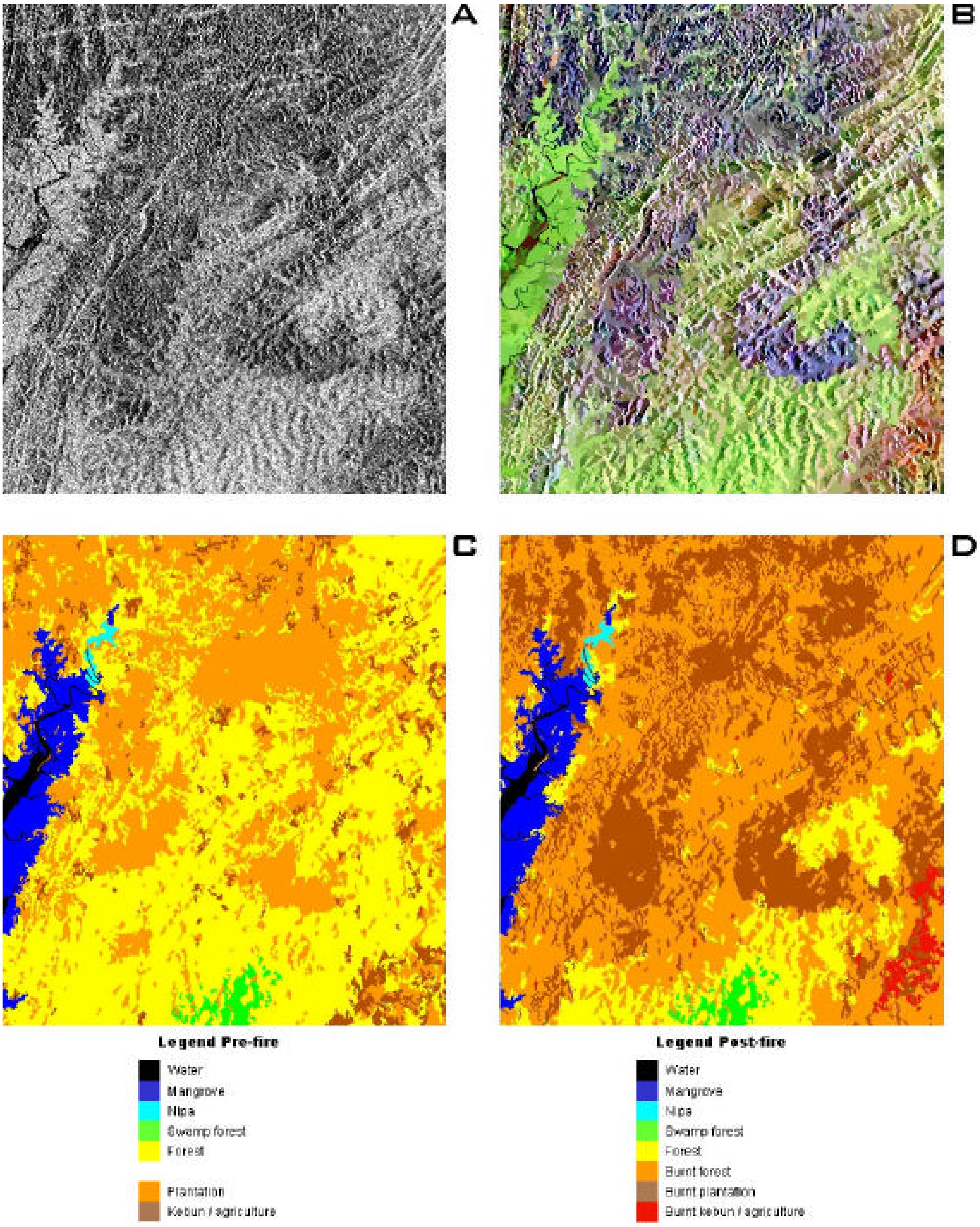

Figure 8 ERS SAR data fragments of an 18 x 20 km^2 area near Balikpapan (East-Kalimantan) located directly west of the Wanariset research station. (a) SAR image of 13 April 1998, (b) multi-temporally segmented SAR image of 2 June 1997, 13 April 1998 and 18 May 1998, (c) pre-fire period classification, (d) post-fire period classification.

VI. ACCURATE MONITORING

It may tentatively be assumed that, at map scales of 1:100,000 and smaller, accurate and up-to-date maps are required to meet several types of information needs. Processes of deforestation, the conversion of forests to other types of land cover, the area of secondary forest and land degradation may be some of the important types of land cover dynamics requiring measurement. Although spaceborne SAR may be quite capable of providing relevant information in the near future, it is not yet clear how such a SAR should be designed in terms, for example, of wave parameters (i.e. incidence angle, polarisation and frequency band) and resolutions.

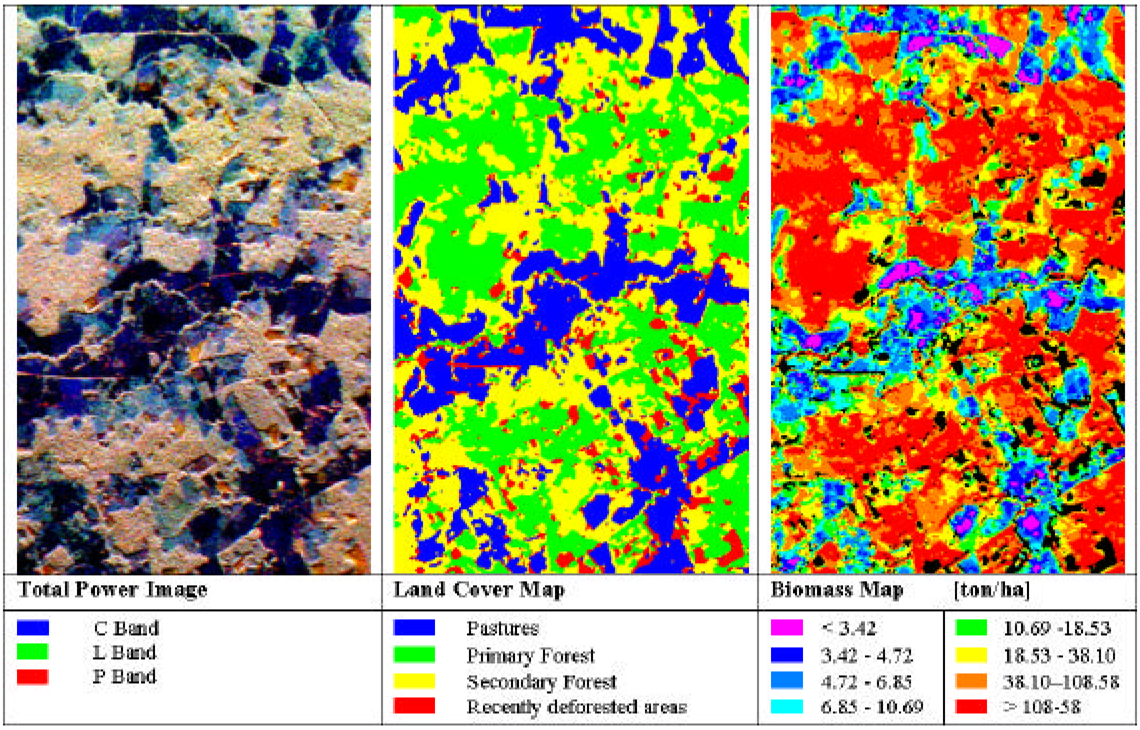

Figure 9 (a) AirSAR Total Power image, (b) Land Cover map and (c) Biomass map, for a 4 x 7 km^2 section of the 40 x 8 km^2 mapped area in Guaviare, Colombia. In the biomass map the areas of recently cut forest are masked (black).

The results of research conducted at a well-surveyed test site of the Tropenbos Foundation in Guaviare, a colonisation area at the edge of the Colombian Amazon, may provide some insight into the above issues. In May 1993, NASA's AirSAR collected fully polarimetric C-, L- and P-band data in this area (Figure 9a), thus facilitating the evaluation of the utility of different wave parameters for different types of information needs.

The most important vegetation cover types in this study area are (1) primary forest, (2) secondary forest regrowth, (3) recently deforested (burnt) areas and (4) pastures. Recently deforested areas are areas where forest has been recently cut and the remnants have been burnt after a short drying period. Crops are usually planted shortly after burning, while large branches, trunks and stumps of big trees remain present for some time. In addition, there are some natural savannahs (5) and bush lands (6) in the westernmost part of the test area.

An appropriate system configuration may be selected on the basis of various results presented by Hoekman and Quiñones (1998, 1999). As an example, the combination of an L-band system with HV-polarisation (Lhv) and a P-band system with right circular polarisation (Prr) may be chosen. This yields good overall classification results, little confusion between any pair of land cover classes and useful information on biomass over a wide range of values. Validation resulted in the very good overall result of 98.6% (Table 6). The resulting land cover class map is shown in Figure 9b.

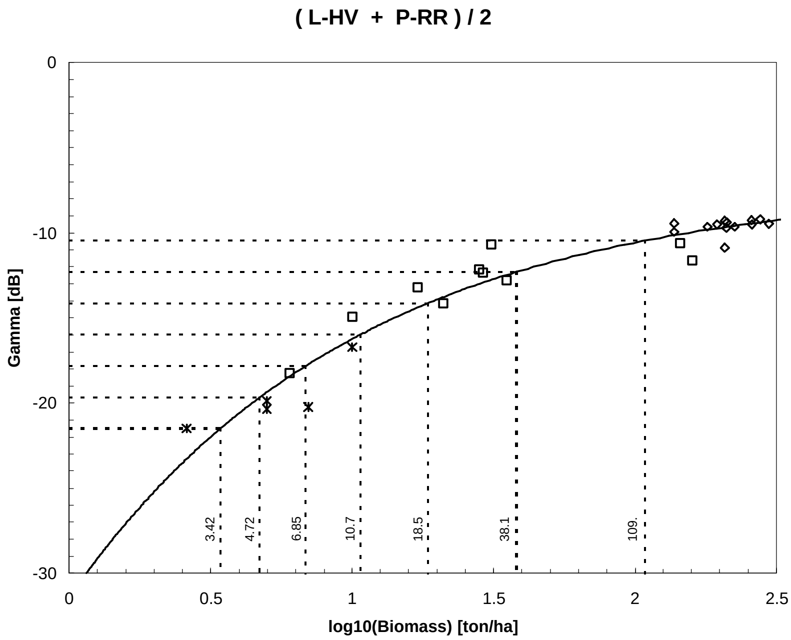

Figure 10 Experimental relationship between biomass and the average back scatter of the Lhv and Prr channels. Eight arbitrarily chosen biomass classes are indicated, corresponding to equidistant values of back scatter separated at 1.96 standard deviation intervals. Symbols relate to cover types: primary forest (), secondary forest ( ), and pasture (*).

A map of biomass classes can be created using the functional relationships between (above-ground fresh) biomass and the average back scatter of the Lhv and Prr bands (Figure 10). This was done for eight arbitrarily chosen biomass classes, namely: (1) ≤3.42, (2) 3.42-4.72, (3) 4.72-6.85, (4) 6.85-10.7, (5) 10.7-18.5, (6) 18.5-38.1, (7) 38.1-109 and (8) > 109 (in tons/ha). Since the relationship does not hold for the class of recently cut areas, these areas have been excluded from the biomass classification illustrated in Figure 9c. It is difficult to validate the accuracy of these results, since acquiring a sufficient number of additional biomass values is a huge task. The consistency between biomass classification and land cover type classification can be checked, however. Table 7 shows the distribution of biomass classes as a percentage of the total area for each land cover class (excluding recently cut areas). The agreement with expected biomass ranges is high for all three land cover types. Very low values of biomass (≤3.42 tons/ha) were classified in areas corresponding to the natural savannahs (in the westernmost part of the study area), which is in agreement with field observations. The same low range was found for some pasture areas (east of the savannahs), indicating low biomass values that may be associated with recent pasture burning or pasture land degradation. The first possibility is less likely, since burning of the pastures usually takes place during the dry season while the images were recorded in the middle of the rainy period. However, although no degradation data are available to support such a hypothesis firmly, the tendency for more lower biomass pastures to be found in the older settlement areas corresponds with expectation. Pastures in the higher biomass range (3.42–10.7 tons/ha) were found to correspond to areas where filed surveys recorded the occurrence of tall grasses and a high proportion of bushes and small palms. Both the secondary and primary forest classes show a distribution over several biomass classes in the middle and higher ranges.

Table 7 Percentages of areas corresponding to the classification of the four main land cover types and the eight biomass classes. The land cover types are encoded as: (1) Primary forest, (2) Secondary forest, (3) Recently cut areas, and (4) Pastures. Shaded boxes in the first column may indicate areas of forest degradation, while shaded boxes in the last column may indicate areas of land degradation.

Biomass classes (ton/ha)	**1**	**2**	**3**	**4**
Masked	0	0	100	0
0-3.42	0	0	0	16
3.42-4.72	0	0	0	18
4.72-6.85	0	1	0	23
6.85-10.7	0	3	0	20
10.7-18.5	1	12	0	12
18.5-38.1	2	28	0	6
38.1-109.	12	40	0	3
>109.	84	14	0	1

It should be noted that the biomass class map shows broad biomass classes over several orders of magnitude and is thus useful for the assessment of spatial patterns associated with land and forest degradation and secondary regrowth. It does not show accurate biomass value estimates and is thus of limited value for, say, foresters who want to assess such parameters as timber volume.

Because the relation between back scatter and biomass depends on land cover type, it may be necessary for accurate biomass assessment to be preceded by a good land cover type classification. Hoekman and Quiñones (1998) show that the combination of good land cover type and good biomass classification may be particularly useful, as it allows for accurate monitoring of land cover type change, deforestation, secondary regrowth (in the lower biomass range, i.e. up to approximately 10 years) and land degradation. For these applications the use of P-band is not strictly necessary and a combination of C- and L-band would suffice. In addition, frequent satellite observation would allow for timely and accurate detection of illegal clear-cut. The use of P-band, currently restricted to airborne operation, is particularly useful for applications like monitoring secondary regrowth (in the higher biomass range) and primary forest degradation.

VII. COMBINED APPROACH

Although each of the above-mentioned techniques has its own intrinsic value for meeting information needs, it is useful to study how these can be combined efficiently within an operational monitoring environment. The fact that certain systems are already operationally available, while other systems are planned, proposed or experimental, makes it necessary to differentiate between short-term and long-term solutions.

In Figure 11 four levels of radar observation are distinguished on the basis of increasing scale and decreasing observation frequency and coverage. At the lowest level, very frequent observations (several times per week) at medium satellite resolution are achieved, completely covering the area of interest (e.g. a whole country). Examples of systems at this level could be ESA's ASAR (to be launched in 2000) in "Wide Swath" mode. A non-radar example is NOAA-AVHRR for fire detection, which is already operational in Indonesia. In "Wide Swath" mode ASAR could detect areas of special interest, which could be subsequently monitored at level 2, using high satellite resolution at a lower observation frequency (roughly once per month) to update mapping or detail selection of areas of interest. A lot of information has already been obtained using ERS SAR images, ranging, for example, from monitoring the expansion of the timber road network and the progress of strip cutting to the detection of small areas (less then 1 ha) of illegal clear-cut and fire damage. When proper use is made of level 2 information, airborne radar (or photography) flights can be planned much more efficiently. High resolution airborne radar can be efficiently applied to the detailed mapping of large areas (see also: Van der Sanden and Hoekman, 1999). An example is the "250,000 km^2 protected forest area" mapping campaign executed by Dornier in Indonesia in 1997. Similar images (from the INDREX campaign) were also found to be useful for the accurate checking of strip cutting and enrichment planting activities. Systems with longer wavelengths (L- and P-band) may be found very useful for mapping forest and land cover type, biomass and forest flooding. At the highest level, individual trees, rather than land cover units, are observed and short-wave, very-high resolution interferometric airborne SAR is required. It can be used in areas with legal logging activities and in areas of special interest identified through the first three levels of observation. On the other hand, where level 4 data are available, these could contribute to mapping accuracy by combining the information with that from level 3 mapping systems.

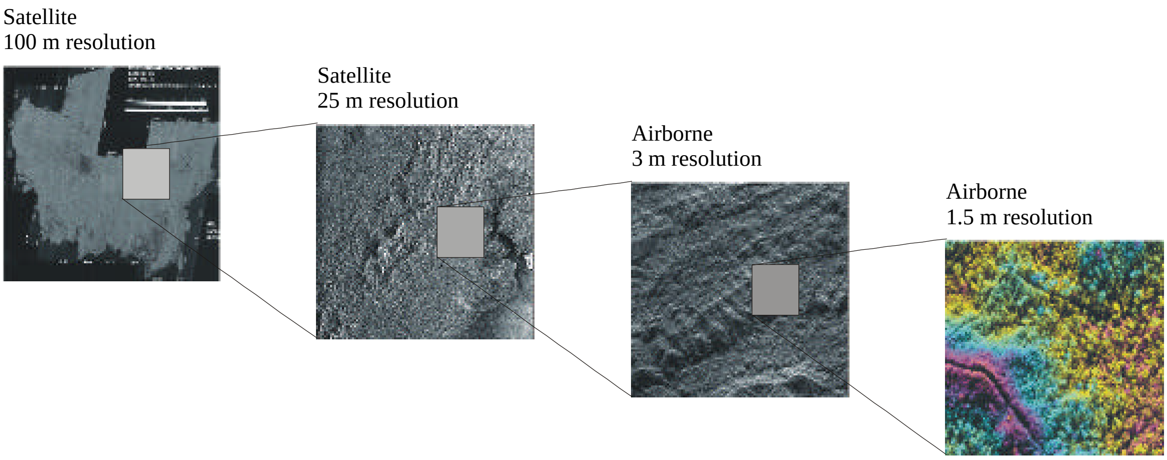

Figure 11 Efficient data acquisition is obtained by a multi-sensor and multi-platform approach. In this example, medium to high resolution spaceborne SAR is used to monitor large areas and to select areas of interest where high to very-high resolution airborne SAR can be directed to collect detailed information.

VIII. CONCLUSIONS AND RECOMMENDATIONS

Information on terrain, forest and tree characteristics is needed to enforce national legislation for sustainable forest management or to verify the implementation of guidelines for sustainable forest management as proposed by the International Tropical Timber Organization (ITTO).

Systems should be available, among other things, to monitor logging activities and to detect illegal logging, allowing timely action to be taken. Because cloud cover severely limits the application of aerial photography for this purpose, the use of airborne radar seems to be a very promising alternative. High-resolution InSAR systems may be well capable providing data at the tree level, while ERS SAR monitoring could be used for timely detection and the identification of areas of interest.

The ERS SAR is an operational system and, in principle, data can be obtained routinely and frequently (every 35 days). The resolution of the ERS SAR is sufficiently high, for example, to detect small areas of illegal logging or to verify the area of plantations and whether obligatory reforestation has been carried out. Alternatively, data from RADARSAT or the future ASAR may be used. The NOAA-AVHRR hot spot monitoring system is also operational and makes two observations per day. In Indonesia, for example, it is already used for operational application in forest management. Combined use of these systems may yield accurate and up-to-date information on fire and fire damage at a national level.

In the future, more advanced spaceborne SAR systems may become available, which will be able to achieve a much higher mapping accuracy and may be utilised for monitoring a wide variety of land cover dynamics at scales of 1:100,000 and smaller.

Airborne surveys in tropical rainforest areas are still incidental and there are still no airborne SAR systems dedicated to operational tropical forest inventory and management. In principle, they are suitable for meeting a variety of information needs in tropical rainforest areas at scales of 1:50,000 and above. Local permanent availability of InSAR tree mapping systems in tropical forest areas, used in combination with other remote sensing systems and satellite monitoring, would certainly be an important step forward in support of achieving a prudent and sustainable forest management.

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NATURAL FOREST GROWTH AND YIELD RESEARCH AT WANARISET SAMBOJA

Robert B. de Kock and Bambang K. Suryokusumo

SUMMARY

In the period 1988-1990, the Tropenbos project re-established a series of growth monitoring plots in the PT ITCI concession. These plots were among a number laid out in the period 1972-1976, when the concession was managed by the American timber concern Weyerhaeuser. After eight or more years of disuse, not all the plots known to have existed could be restored, partly because of land clearing, but also because all the markings had been obliterated.

The 14 restored plots total 11.55 hectares and vary in size between 0.25 and 2.0 hectares. 57% of the area is in relatively untouched forest and the remainder consists of logged-over forest. The original survey data do not include pre-logging figures for all plots. The lower diameter measurement limit was 15 cm and species identification was by local names.

The restoration put the maintenance standard on an accepted scientific footing in line with FAO recommendations. It involved the re-establishment of boundaries and 10 x 10 metre internal subdivisions and remeasurement, as well as complete botanical identification of all trees over 10 cm dbh. A great deal of structural and chemical soil information was also collected at this time. More recently, the topography of the plots was surveyed in detail and the boundary and internal markers upgraded to withstand a 5-year non-measurement interval without fatal decay.

The restored plots have been remeasured at an average frequency of 2.5 years, but the remeasurements were irregularly spaced in time because of logistical and financial constraints. Remeasuring campaigns are costly (in the order of a few hundred dollars per hectare) and, for the future, the frequency of remeasurement is targeted at 5 years. This makes quite heavy demands on the quality and maintenance of field markings and measuring above buttresses.

All data are made publicly accessible through the offices of the BPK Samarinda Growth and Yield Data Clearing House, which also contains data from other research projects as well as from concession-operated permanent plots all over Kalimantan, all in a common data format. Users to date have been mainly scientists, but the data are also beginning to be used to supplement data for operational planning. Even so, the data set remains a relatively underused resource and it is strongly recommended that further studies make use of it for growth modelling and other purposes and publish the results. Efforts are underway to promote this in the form of an international workshop sometime in the year 2000.

The unequal size and orientation of the plots, the pre-restoration time gap in the measurements, the relative uniformity of the forest type and differences in measurement standard detract from the value of the data. On the other hand, the data set covers the longest time period of any known plot series in Kalimantan dipterocarp forest.

The recent Kalimantan forest fires have affected the plots quite severely. During the catastrophic 1997-1998 season the plots, mainly but not exclusively the logged-over ones,

sustained extensive damage. A preliminary assessment indicates damage to 10 out of 14 plots, with 6 classified as "lightly damaged", 3 as "average" and 1 as "severely damaged". Nonetheless, the majority of the plots are worth keeping. Monitoring their post-fire recovery will improve our ability to judge the long-term cost of fire damage, a concern that is likely to become more important over time.

INTRODUCTION

An important cornerstone of the sustainable management of natural forest under selection-cut regimes is the fine-tuning of periodic harvests, so that the productivity of the stand remains optimal and depletion does not occur. This is the aim of Growth and Yield research. The greatest bottleneck in Growth and Yield analysis for natural rainforest is a general lack of long-term reliable historical measurement data over a sufficiently wide range of site and stand conditions.

The situation is no different in Indonesia, where the management prescriptions have been designed on the basis of the merest guess at post-harvest increments. While this has led to generally acceptable secondary stands in those areas where logging was carefully done and post-harvest damage prevented, a great deal more data analysis is needed to achieve adequate and sustainable productivity management (de Kock, 1999).

The Tropenbos Foundation and the Forest Research Institute Samarinda have been acutely aware of the need for growth data since their Wanariset Samboja project was set up. It was recommended at a Tropenbos expert meeting held in 1987 that the quickest way to generate meaningful data would be to build on measurement series already available. In preference to laying out new plots, the project should try to address the problem by rehabilitating any measurement series in the general work area that were susceptible to a revival. This would have the advantages of not having to start everything from scratch, of not wasting the time and energy already invested in layout and data collection, and of generating useable data in a relatively short period of time (van Eijk-Bos and Gelens, 1987).

As it happened, the project was in a position to act upon this recommendation. From approximately 1968 until 1982, the International Timber Company Indonesia (P.T. ITCI) at Balikpapan—at the time a joint venture between the Indonesian group P.T. Tri Usaha Bhakti and Weyerhaeuser Inc. of the USA—had established several permanent plots. By kind permission of P.T.ITCI, the Tropenbos research group gained access to the relevant research archives and the company granted access to the concession area and facilities. Some of the original plots were no longer in forest and others could not be relocated on the ground after six or more years of neglect, but some very suitable plots established in 1976 and 1977 were amenable to rehabilitation (van Eijk-Bos 1997).

In the event, 13 plots totalling 11.55 hectares (6.54 ha in virgin and 5.01 ha in logged-over forest) were selected for rehabilitation. One of these was later subdivided into two parts on the grounds of its uneven logging history. Two plots logged in 1971 were laid out apparently as an afterthought in 1972, but serious records date only from 1976/77. The plots vary in size from 0.25 ha to 2 ha and differ also in other aspects such as orientation. The original management and recording regime as designed by Carmichael and Hughes (1977) was maintained at one or two-year intervals until 1981/82. Although the data are in general agreement with established standards, there are a few differences. The original ITCI data records all stems above 15-cm dbh, whereas the FAO and the Oxford Forestry Institute (Synnott, 1979) recommend 10 cm. This was amended with the start of the Tropenbos measurements in late 1988. There are also some minor variances from accepted practice in the coding of stem and crown classes, which have subsequently been revised in the Tropenbos measurement regime.

Regeneration subsamples were collected at the start of the Tropenbos rehabilitation, but these data have never been analysed and the exercise has not been repeated.

SITE AND FOREST CHARACTERISTICS

The altitude of the plots ranges from 100 to 420 m above sea level. The relief is characterised by steep slopes and narrow crests and valley floors, forming part of asymmetric hills or ridge systems. The lithology is dominated by alternating layers of sandstone, claystone [mudstone and siltstone of varying thickness. Van Bremen et al. (1990) did not observe much difference in lithology between or within the plots. Over 80% of the area of the plots was classified as consisting of strongly weathered, very deep, for the most part moderately well drained, acid, clayey Ultisols with a thin A horizon and low nutrient status. Some 15% were classified as less weathered Inceptisols. In one plot, Spodosols (Podzol) have developed on coarse sandstone and this plot bears an anomalous forest type, rich in *Agathis borneensis*. Chemical analysis (Oldeman, 1991) points up strong to excessive acidity (pH-H_2O 3.5 - 4.5 on surface, 4.6 - 5.0 in subsurface horizons) with low to very low nutrient status and aluminium concentrations reaching toxic levels. Slightly more favourable conditions are found on lower slopes and valley floors.

The plots are all in the Production forest (Hutan Produksi) land class, although some are in compartments set aside for genetic resource protection. Where logging has taken place, this was done according to an early version of the Indonesian Selection Cut System (TPI), with a lower diameter limit of 50 cm for all harvested species.

PECULIARITIES OF THE RESTORATION PROJECT

It is indicative of the perishable nature of any markings that six years of non-maintenance had made the restoration of the plots only narrowly feasible, even though van Eijk-Bos (1997), who was principally responsible for the project, notes that “ITCI had been very thorough in laying out the plots, in documentation and in marking the trees.” Over the successive years, therefore, the Tropenbos measurement teams have upgraded ground and tree markings to a very sturdy condition, carefully re-recorded the tree positions in the plots, and taken GPS readings, so that the plots are now hopefully amenable to remeasurement every 5 years rather than the researchers having to return each or every other year. To date, the Tropenbos measurements have been taken on average every 2.5 years, but were irregularly spaced in time because of logistical and financial constraints. A 5-year measurement cycle would be more in line with the budgetary requirements of a research organisation and would not greatly detract from the value of the data as compared with a higher frequency of measurement.

The original plot layout included subdivision in 10x10 m marked subdivisions, with the tree positions measured relative to that grid. This grid has been carefully restored. The sturdiness of these internal plot markers was a major factor in the success of the restoration project.

The internal markers later formed the basis for a thorough topographic survey of each plot. One or two access points on a road were measured with GPS equipment and the access path staked out with heavy timbers whose positions were also measured.

The time gap in the measurements immediately prior to the Tropenbos restoration has caused some problems with the measurement of buttressed trees, because generally the point of girth measurement was not moved upward soon enough. However, experience has shown that reasonable results are possible with the application of a suitable taper function.

A more serious problem with the older ITCI data is that species identification is incomplete. It refers solely to local names and is generally subject to some doubt. For trees still alive, the Tropenbos team was able largely to correct the shortcomings in identification, but for trees no longer present, the information was irretrievably lost. The older data cannot therefore be used for mortality analysis by species group. Under Tropenbos management, all trees have been botanically identified to species level, except for some difficult and commercially relatively unimportant genera, such as *Eugenia*. Ingrowth continues to be identified in this manner while spot checks are run on existing identifications in order to check the consistency of identification.

An attempt to classify the plots by species composition yielded a fairly clear distinction between a vegetation type containing *Agathis borneensis* (on mid slopes with an extreme Podzol) and one without. Otherwise the distinctions were less clear. As elsewhere in East Kalimantan, sites with a relatively high incidence of *Shorea laevis* (near ridge tops) and others with a relatively high incidence of *Eusideroxylon zwageri* (on lower slopes) appear to exist in the field, but this result could not clearly be derived from the available data. Van Eijk-Bos (1997) attributes this to the finely dissected terrain relative to the large tree sizes, and recommends treating these subtypes as internal variants of the same forest type.

The plots have been classified into virgin and logged-over categories, but that distinction is really about whether mechanised logging has taken place, and the term “virgin” must be taken with a grain of salt. In most of these plots some human interference is in fact apparent, ranging from incidental cutting of scattered *Eusideroxylon zwageri* for roof shingles to clearing of undergrowth for experimental rattan planting. However, the virgin plots have a fairly uniform basal area averaging 34 m^2ha^{-1} and this is within the range considered normal both for East Kalimantan lowland dipterocarp forest and for conditions found in lowland rainforest worldwide (van Eijk-Bos, 1997).

The unequal size and orientation of the plots, the pre-restoration time gap in the measurements, the relative uniformity of the forest type, uncertain or absent pre-logging data, the absence of predefined buffer zones, and differences in measurement standard all detract somewhat from the value of the data. On the other hand, the data set covers the longest time period of any known plot series in Kalimantan dipterocarp forest and this warrants acceptance of a few discrepancies.

USAGE AND DISTRIBUTION OF DATA

All the measurement data has been made available to the Forest Research Institute Samarinda for inclusion in the Growth and Yield Data Clearing House in a common format with data originating from other sources in Kalimantan. It is in this wider framework that the data assume more than local importance, since a much wider range of site conditions can be analysed from the augmented data set. Data from the Clearing House will be made available to researchers on application.

An example of analysis for yield regulation using ITCI-Tropenbos data from this source is found in de Kock (1999). The model presented there indicates, for this forest, that a basal-area based logging rule prescribing logging back to 23 m^2ha^{-1} whenever the stand grows to 29.2 m^2ha^{-1} would give a commercial yield (maximum Mean Annual Increment) of 1.79 $m^3ha^{-1}yr^{-1}$. The resulting felling cycle would be about 38 years and marginal yield improvement might be possible with a shorter cycle, but this requires better logging economy and lower logging impact. The existing TPTI rule is clearly inferior to this result, as well as being unsuitable for long-term planning purposes, because as it is a fixed area-based rule, it disregards differences in site productivity.

FIRE DAMAGE

As might be expected, the increasing risks of fires do not pass these plots by. The plots sustained extensive damage during the catastrophic 1997-1998 season, mainly but not exclusively to the logged-over plots. A preliminary assessment indicates damage to 10 out of 14 plots with 6 classified as “lightly damaged”, 3 as “average” and 1 as “severely damaged”. These results are summarised in Table 1.

Table 1 Damage inflicted by 1997 - 1998 Kalimantan forest fires

A. By number of plots					
Damage class:	**None**	**Light**	**Medium**	**Severe**	**All damage cl.**
Forest status					
Logged	1	4	1	1	7
Virgin	3	2	2	-	7
Total	4	6	3	1	14

B. By area affected					
Damage class:	**None**	**Light**	**Medium**	**Severe**	**All damage cl.**
Forest status					
Logged	0.5	3.17	0.84	0.5	5.01
Virgin	1.64	3.65	1.25	-	6.54
Total	2.14	6.82	2.09	0.5	11.55

Pending further investigation, it may be justifiable to say that these plots have now lost much of their value for ordinary growth analysis. However, since the state prior to the fires is quite accurately known, they have now become a valuable resource for the study of natural regeneration after fire damage, since this is an important factor in judging the overall and long-term economic and ecological impact of increased fire frequency. The long-term cost of fire damage is a subject that has not been adequately studied, but is steadily gaining in significance. It is therefore recommended that the plots be preserved and managed as before unless the damage is near-total.

CONCLUSIONS AND RECOMMENDATIONS

By rehabilitating these growth-monitoring plots the Tropenbos project has shown that it is sometimes possible to create a source of growth and yield data with a relatively small investment in time compared to laying out plots from scratch. While it is true that this procedure has produced a slightly odd collection of plots, with some notable gaps in the data, the disadvantages of this do not outweigh the advantage of creating a long monitoring history. The original experts' recommendation has paid off in this respect and this may be worth noting for other projects.

The strong points of this data set are its long history and very good species identification, as well as its inclusion in the Kalimantan Growth and Yield Data Clearing House in a common format with other data sources. Yet the data remain an underutilised resource and researchers are urged to explore the possibilities of doing more analysis on this and other Kalimantan growth data.

Obvious applications include growth modelling for management, but the data in conjunction with the field plots may also be suitable for the selection of superior individuals for propagation, the development of guidelines for forest valuation, and ecological modelling.

Although the plots sustained considerable damage in the 1997-1998 forest fires, it is recommended that they continue to be monitored. Since their pre-fire condition and history is accurately known, they will form a valuable resource for regeneration monitoring.

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TREE DIVERSITY IN THE RAIN FORESTS OF KALIMANTAN

Kade Sidiyasa

ABSTRACT

Kalimantan, which has large areas of forest, encompasses a variety of forest types comprising mangrove forest, coastal forest, swamp forest, evergreen tropical rainforest, forest over limestone and heath forest, and stretching from sea level up to 2556 m altitude. The mixed dipterocarp forests are situated mostly in lowland areas, below 600 m altitude. Very few Dipterocarp species occur at high altitudes, i.e., *Hopea mengerawan, Shorea curtisii* ssp. *curtisii, Shorea* sp. and *Vatica oblongifolia*. The high quality timber species *Agathis endertii* is found only at an altitude of 1450-1600 m, where it mainly grows together with some species of *Lithocarpus, Nageia wallichiana* and *Podocarpus neriifolius*. Eugenia spp., Adinandra and Lithocarpus dominate vegetations on the mountain peaks of Mt. Lunjut and Mt. Mencah (Kayan Mentarang National Park). A typical highland species, *Weinmannia borneesis* is also found here. *Tristaniopsis* sp. can be dominant on very steep and rocky slopes. *Shorea balangeran* and *Cratoxylum glaucum* usually grow on peat or kerangas forests, whereas *Gonystylus bancanus, Alstonia pneumatophora, Alstonia spatulata, Combretocarpus rotundatus, Dactylocladus* and *Lophopetalum javanicum* are adapted to the swampy areas.

Detailed information on the vegetation (trees) of Sungai Wain Protected Forest in East Kalimantan is presented. In a plot area of 3.6 ha, divided into 9 subplots, 385 tree species with the dbh of 10 cm or more were recorded. These species belong all to 143 genera and 49 families. The species composition in the different subplots sometimes varies greatly. Ranked by importance of species, *Shorea laevis, Madhuca kingiana, Eusideroxylon zwageri, Shorea smithiana, Koompassia malaccensis and Drypetes kikir* are the dominant species in the subplots.

INTRODUCTION

The forests of the Malaysian region are very species-rich in all groups of biological organisms. Of the estimated 42,000 vascular plant species (Roos, 1993) or from the 25,000 species of flowering plants according to Whitmore (1990), the vast majority occur in forest ecosystems, and a very high proportion of these plant species are trees and large shrubs. Kalimantan, which has large area of forest, is believed to be one of the islands that still harbours numerous unknown and endemic species that have not yet been described. This is a reasonable assumption because, in the area of flora, most of the biologists (especially botanists) agree that the Indonesian provinces of Kalimantan area are still under-collected. Relatively few botanical explorations have been made in the past. In the period 1989–1999, collections by the staff of the Wanariset Herbarium added more than 11000 items to the collection of Kalimantan (Sidiyasa *et al*., 1999). These collections comprise mainly trees from the East Kalimantan area.

Borneo, including the Indonesian provinces of Kalimantan and the Malaysian states of Sarawak, Sabah and Brunei, is the largest island in the Sundanic biogeographical subregion. It is a centre for many genera and species of the Malaysian flora. It is said that Borneo is also the home of the South East Asian Dipterocarps. According to Newman *et al*. (1998), there are 273 species and

20 subspecies of Dipterocarpaceae in this area. Most of the island comprises undulating hilly lowland and swampy plains. The Kalimantan part reaches from sea level up to 2556 m altitude. The highest peak is unnamed and is located above the headwaters of the Bahau River in East Kalimantan. The climate is humid, with a rainfall varying between 2000 and 4000 mm/year. The FAO (1981) described Borneo as an island covered by a continuous carpet of evergreen rain forest dissected by swirling brown rivers. Today, a lot of forest areas have been cleared for timber, agricultural land, industries and resettlement. Forest fires in 1982/1983 and 1997/1998 had a disastrous impact on remaining forest conservation areas. Soon, after the forest cover had been removed, people who live nearby, automatically extended their ladang area into the conserved forest lands.

Kartawinata *et al*. (1981), Bratawinata (1986), Sidiyasa (1987, 1995) and Riswan (1987), among others, have already published information and detailed studies on the structure and the species composition of forests at some places in Kalimantan. However, much more research is still needed. The present paper elaborates on the results of the research on tree species diversity in primary forests carried out by the MOFEC-Tropenbos-Kalimantan Project during its existence in this area (since 1987). Literature study is also incorporated in order to provide more adequate information.

GENERAL FLORISTIC DIVERSITY OF KALIMANTAN

Lowland forest

The area where lowland forest occurs refers usually to the area below 700 m above sea level, and does not include specific habitats like kerangas forest, swamp forest, coastal forest and mangrove forest. Most of the Kalimantan forests are in this category, where the Dipterocarp species may be dominant. In many cases, the dominance of the Dipterocarpaceae in the area is related to their trunk or bole sizes, which is usually very large. It is different from the family of Euphorbiaceae, which is also very often dominant, but the dominance is related to the higher number of genera and species found.

Nine genera of Dipterocarpaceae are found in Kalimantan. They are *Shorea, Anisoptera, Parashorea, Dipterocarpus, Cotylelobium, Dryobalanops, Hopea, Vatica* and *Upuna*. From the 10 genera of the Malaysian Dipterocarps, only *Neobalanocarpus* has not been recorded from Borneo so far. This species occurs in Thailand and in Peninsular Malaysia.

As the most suitable habitat, it is well known that the lowland forests consist of the highest diversity of plants, especially trees. The most durable timber species “iron wood” (*Eusideroxylon zwageri*) is mostly adapted to flat lands along rivers, sometimes dominant, and it is extremely slow growing. Sidiyasa (1995) found this species was also growing well on undulating areas in Sintang, West Kalimantan.

Other common and important tree species in lowland primary forests in Kalimantan are *Koompassia excelsa, Pometia pinnata, Dracontomelon dao, Durio* spp., *Artocarpus* spp., and *Dialium* spp., These species, except *Koompassia excelsa*, are important and well known because of their fruits, which are edible. *Sindora* spp. and *Palaquium* spp. are known for their timber quality. *Pometia pinnata* and *Dracontomelon dao* are some of the trees which usually grow along the rivers and small tributarys. Pometia *pinnata* especially is very easy to distinguish in the field because of its young leaves, which are dark red.

Montane forest

It is already well known that, in most places at higher altitudes, the diameter of trees tends to be smaller than that of trees growing at lower altitudes. This characteristic is very obvious when the habitats are rocky or are higher than 1600 m altitude. Very few Dipterocarp species occur at this level. During our botanical exploration in the Kayan Mentarang National Park (Mt. Lunjut and Mt. Mencah), four species of Dipterocarpaceae were collected. They are *Hopea mengerawan, Shorea curtisii* ssp. *curtisii*, *Shorea* sp. and *Vatica oblongifolia*. *Shorea curtisii* ssp. *Curtisii,* in particular. is found at the altitude of 1000 - 1600 m. The high quality timber species *Agathis endertii* is found only at an altitude of 1450-1600 m. It grows mainly together with some species of *Lithocarpus, Nageia wallichiana* and *Podocarpus neriifolius*. At the top of Mt. Lunjut (1900 m), *Eugenia* spp. are very dominant, while on Mt. Mencah (1980 m) the vegetation is dominated by *Adinandra* spp. and *Lithocarpus*. A typical highland species, *Weinmannia borneesis,* is also found here. *Tristaniopsis* sp. which is easily recognised from its filling and red-orange outer bark can be dominant on very steep and rocky slopes.

Heath forest

In Kalimantan and the other parts of Borneo, this forest formation is called 'kerangas'. The forest grows on very acid soils, that usually consist of white sand.Nutrients are therefore very low and rice will not grow. The most common tree species that occur in kerangas forests are *Shorea balangeran, Cratoxylum glaucum* and *Eugenia* spp. Some species of *Lithocarpus* and *Buchanania arborescens* also occur here. In Sarawak, *Casuarina nobilis* and *Calophyllum incrassatum* were also recorded (Whitmore, 1990).

Swamp forest

Depending on the type of the habitat of its occurrence, this forest is may be called 'peat swamp forest', if it occurs in a wet area with waterlogged condition, or 'freshwater swamp forest', if it occurs in an area where flooding is periodic, either daily, monthly or seasonally. In peat swamp forest, some tree species such as *Gonystylus bancanus*, *Alstonia pneumatophora, Alstonia spatulata, Cobretocarpus rotundatus* (Anisophylleaceae), *Dactylocladus* and *Lophopetalum javanicum* grow particularly well. In freshwater swamp forest many more species are usually adapted to the habitat conditions. *Calophyllum* spp., *Eugenia, Vatica venulosa, Horsfieldia* spp. are common here.

STRUCTURE AND SPECIES COMPOSITION OF SUNGAI WAIN FOREST

Introduction

The forest of the Sungai Wain Protected Forest (SWPF) is the remaining tract of primary lowland forest nearest to the large cities in East Kalimantan. The forest is located only 15 km north of the Balikpapan city, along the Balikpapan - Samarinda main road. The total area is about 10,000 ha. Unfortunately, local communities occupy part of the area, especially along the Balikpapan - Samarinda main road. According to Sukmajaya *et al*. (1999), about 360 ha have been already converted into agricultural land by 147 families. In addition, more than 50 percent was affected by forest fires in 1997/1998.

As the only primary forest remaining near a big city like Balikpapan, the Sungai Wain forest has a very important function, economically as well as ecologically. Much research on flora or fauna, including their ecosystems, has been or still is being done here. This area supports populations of sun bear (*Helarctos malayanus*), red monkey (*Presbytis rubicunda*), orang-utan (*Pongo pygmaeous*) (Orang-utan Reintroduction Project) and a wide range of other rare endemic fauna and flora species. The forest also provides non-timber forest products for the people living around the Sungai Wain FR and it serves as the main water catchment area supplying the immense oil refinery industry in Balikpapan.

The aim of this study is to obtain detailed information on forest structure and tree species composition (diversity) and to compare these characteristics with other forest sites, mainly in Kalimantan, Sarawak, Sabah and Peninsular Malaysia.

Plot establishment and site description
Following an extensive field orientation, nine permanent subplots, each 200 x 20 m (0.4 ha), totalling 3.6 ha, were established in the Sungai Wain PF. In order to facilitate the inventory, the subplots were divided into 10 x 10 m units. Ironwood poles of 5 x 5 x 130 cm were used as the corner (border) markers of each subplot. Slope corrections were made for horizontal distances. The main terrain characteristics of the subplots were:

- subplot 1: consists mostly of flat land, which is located on a small tributary of the Wain river;
- subplot 3: on lower and middle slope, a small part on a small tributary of the Wain river;
- subplot 5 undulating area on a small tributary of the Wain river;
- subplot 7, upper slope, ridge and a little part in a swampy area;
- subplot 9, slope and flat land on a small tributary of the Bugis river;
- subplot 11, undulating;
- subplot 13, undulating, partly swampy and small tributaryof the Bugis river;
- subplot 15, slope and a small part in the swampy area;
- subplot 17, ridge, slope and small tributary of the Bugis river.

The forest in the plots was considered primary forest, but there has probably been some illegal logging and damage by storm in the past. Many big trees had fallen, probably because of the loose soils, which are mostly sandy.

Data collection
All trees with a dbh 10 cm or more (dbh = diameter at breast height, 130 cm above ground level) or if buttresses present, about 30 cm above buttresses, were measured in all nine subplots. The position where the measurement was made was marked by red paint (a horizontal ring around the tree bole). All trees in the subplots were numbered permanently, using aluminium tags. Preliminary tree identification was made in the field, but later a detailed identification was made in the herbarium at the Wanariset station. All specimens (plant samples) which could not be identified with certainty to the species level were collected. These (paucher) specimens were also important for identifying the total number of species, even if the plants were not fully identified to species level; in which case, a numeric coding system was used, e.g. *Baccaurea* sp.1, *Baccaurea* sp.2, *Garcinia* sp.2, etc.

Data analysis
The Important Value index (I.V.) of Cottam and Curtis (1956) is used to describe and compare the species dominance of the subplots. The I.V. of the taxon of each subplot is defined as the sum of its relative density and relative dominance; while, in order to describe the dominance of species in the whole plot, the I.V. is defined for the whole plot (all 9 subplots) - - by adding its relative frequency. The following equations are used:

$$\text{Relative density} = \frac{\text{Number of individuals of a taxon}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of a taxon}}{\text{Total basal area of the subplot}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of a taxon}}{\text{Total frequencies of all taxa}} \times 100$$

Result

Forest structure

Based on the data collected in the whole plot area of 3.6 ha, the forest in the Sungai Wain FR has a density of 535 trees/ha and a basal area of 23.5 m2/ha (Table 1 shows the tree density and basal area of each subplot). The tree density is more or less similar in most subplots, with a variation between 470 trees/ha in subplot 5 and 712 trees/ha in subplot 17. There is no distinct correlation between the tree density and basal area found in the subplots. As shown in Table 1, the forest in subplot 7 has the largest basal area of 30.2 m2/ha, with a density of only 500 trees/ha. In subplot 17 the density of 712 trees/ha is much higher than that in the other subplots, but here the basal area is only 23.1 m2/ha (lower than those found in subplots 5, 7 and 11).

Table 1 Tree density and basal area of nine subplots in the Sungai Wain forest

No. of subplots	Characteristic of subplot	Tree density (trees/ha)	Basal area (m^2/ha)
1	Flat, small stream	524	22.6
3	Slope, small stream	500	22.8
5	Slightly undulating, small stream	470	29.6
7	Slope, ridge and swampy	500	30.2
9	Slope, flat and small stream	505	18.8
11	Undulating	502	24.9
13	Undulating, small stream and swamp	505	19.9
15	Slope and a little swamp	555	19.6
17	Ridge, slope and small stream	712	23.1

The very high tree density in subplot 17 (712 trees/ha) is an exception. The forest in this subplot is in very good condition. The number of trees with a diameter of more than 60 cm in this subplot is higher than in the other subplots (except subplot 1), which have only one or two trees of more than 60 cm in diameter.

Comparison with some other forest areas in Kalimantan, Sarawak, Sabah and Peninsular Malaysia shows that the forest in Sungai Wain has the lowest basal area (see Table 2). This low basal area is probably due to the small diameter of the trees in the Sungai Wain PF. In the whole plot area of 3.6 ha, only 18 trees with the diameter of more than 60 cm were recorded. In the "Matthijs" permanent plot in the Wanariset Forest with a plot area of 0.51 ha, 10 trees with a dbh of more than 60 cm were recorded, and in a plot of 1.12 ha in the Apo Kayan forest 19 such trees were found (van Valkenburg, 1997).

Table 2 Tree density and basal area in primary forest plots in Kalimantan, Sabah, Sarawak and Peninsular Malaysia

Site	Area (ha)	Density (trees/ha)	Basal area (m^2/ha)	Reference
Kalimantan				
Wanariset (plot Matthijs)	0.51	518	32.3	van Valkenburg (1997)
Wanariset	1.6	541	29.7	Kartawinata *et al*. (1981)
Lempake	1.6	445	33.7	Riswan (1987)
PT. ITCI	4.9	599	41.8	van Valkenburg (1997)
Apo Kayan	1.12	570	35.5	van Valkenburg (1997)
Apo Kayan (Fagaceae plot)	0.8	719	36.0	Bratawinata (1986)
Sungai Wain	**3.6**	**535**	**23.5**	**present study**
Sarawak				
Gunung Mulu	1.0	778	57.0	Proctor *et al*. (1983)
Sabah				
Danum Valley	8.0	434	26.3	Newbery *et al*. (1992)
Danum Valley	1.0	431	42.8	Kamarudin (1986)*
Peninsular Malaysia				
Sungai Menyala	1.62	488	32.9	Wyatt Smith (1966)

*) As cited in Newbery *et al*. (1992).

There are three very big trees (with a dbh more 100 cm) in Sungai Wain PF sample plot. One of these trees is *Dipterocarpus cornutus* and the other two are *Shorea laevis*. The largest diameter, 122.6 cm, is a *Shorea laevis*. All of these species belong to the heavy Dipterocarps group. The largest size for ironwood (*Eusideroxylon zwageri*) was 75.2 cm in diameter in subplot 5, where this species is also the dominant species.

In terms of tree density (see Table 2), the Sungai Wain plot as well as the forest plots in the Wanariset area (Kartawinata *et al*., 1981and van Valkenburg, 1997), and the plot in Lempake (Riswan , 1987) may be considered as representative for the Balikpapan-Samarinda area. The very high density for the forest plot in Apo Kayan described by Bratawinata (1986) in a Fagaceae forest may be the highest one in Kalimantan so far.

Species composition

In the plot area of 3.6 ha, 385 tree species (dbh 10 cm or more) were recorded. They belong to 143 genera and 49 families. Based on number of species of each family, Euphorbiaceae is the most dominant family (consist of 47 species), followed by Lauraceae (28 species), Myristicaceae (27 species) and Myrtaceae (24 species). The ten most common families in the present study in Sungai Wain PF as well as in studies in primary forest plots in some other places in East Kalimantan, are presented in Table 3.

In the family Euphorbiaceae, *Baccaurea* is the most common genus (with 10 species) followed by *Aporosa* (9 species) and *Cleistanthus* (8 species). In the family of Lauraceae, 10 genera were recorded, led by *Litsea* consisting of 11 species. The family of Myristicaceae was dominated by *Knema* (11 species); while the family of Myrtaceae was dominated by *Eugenia* (21 species).

Eugenia is one of the most common genera; it was found in every subplot. The exception was subplot 1, where only one tree of *Eugenia* was recorded. In the other subplots the genus occurred usually more, with up to 18 trees belonging to 9 species in subplot 9. Depending on the species, some tend to grow on flat land and along streams and some others on slopes or ridges.

Table 3 The highest ranking ten families of trees (dbh > 10 cm) at various sites in East Kalimantan based on number of species, except for ITCI plots and the Apo Kayan plot, which are based on Importance Value

Families	**Sungai Wain***		**Wanariset[1]**		**Lempake[2]**		**Apo Kayan[3]**	**ITCI 76-3a 76-b[3]**	**ITCI 72-8 76-4[3]**
	Spec.	(rank)	spec.	(rank)	spec.	(rank)			
Euphorbiaceae	47	(1)	26	(1)	32	(1)	2	2	3
Lauraceae	28	(2)	14	(2)	18	(3)	5		2
Myristicaceae	27	(3)	12	(5)	10	(7)			9
Myrtaceae	24	(4)					4	3	6
Dipterocarpaceae	19	(5)	14	(2)	12	(6)	1	1	1
Fagaceae	19	(5)					3	8	5
Leguminosae	17	(7)						10	
Burseraceae	15	(8)	11	(6)	9	(8)	5	5	
Annonaceae	15	(8)	8	(8)	22	(2)	10	9	8
Anacardiaceae	12	(10)						7	
Also included in the top ten in Wanariset, Lempake, Apo Kayan and ITCI									
Meliaceae	9	(14)	13	(4)	13	(5)			7
Rubiaceae	11	(11)	8	(8)	15	(4)			
Sapotaceae	11	(11)	12	(5)	5	(9)	7	4	4
Moraceae	11	(11)					9		
Bombacaceae								6	
Polygalaceae							8		

* = present study; [1] = Kartawinata *et al*. (1981); [2] = Riswan (1987); [3] = van Valkenburg (1990)

The sweet edible (pulp) fruit of *Baccaurea macrocarpa* is found in subplots 1, 5, 7, 11, 13 and 17. Some other common fruit tree species were found in the area, such as *Artocarpus anisophyllus, Artocarpus dadah, Arstocarpus nitidus, alangium* spp. and *Bouea oppositifolia*.

The dominance of species in each subplot was determined on the basis of the I.V. of each species (see Table 4). *Shorea laevis* and *Madhuca kingiana* appeared to be the most common species in the plot area. Each was found to be dominant in three subplots. *Shorea laevis* was always dominant in areas with relatively dry soils and on upper slopes and ridges; while *Madhuca kingiana* prefers the slightly wet habitat, on lower slopes and flat land.

Table 4 The dominant species on every subplot in Sungai Wain forest based on Importance Value (I.V.)

No. of Subplots	**Dominant species**	**Number of trees**	**Basal area (m^2)**	**I.V.**
1	*Madhuca kingiana*	36	0.971	27.350
3	*Madhuca kingiana*	48	0.804	32.806
5	*Eusideroxylon zwageri*	11	1.449	24.467
7	*Shorea laevis*	7	1.784	21.823
9	*Drypetes kikir*	11	0.558	12.865
11	*Madhuca kingiana*	12	0.318	9.168
13	*Shorea smithiana*	2	1.530	20.231
15	*Shorea laevis*	4	1.071	15.465
17	*Shorea laevis*	9	1.091	14.967

Eusideroxylon zwageri, which is now said to be becoming rare, is dominant in subplot 5, in a slightly undulated flat stretch along a small tributary of the Wain river. This species grows mainly in the company of *Dipterocarpus tempehes*, *Madhuca kingiana* and *Shorea johorensis*.

Compared with other forests in other sites in Kalimantan, Sarawak, Sabah and Peninsular Malaysia, as shown in Table 5, its seems that the species composition of the Sungai Wain forest is rather rich. Probably, only the Apo Kayan plot is richer than the Sungai Wain plot. The much smaller Apo Kayan plot of 1.12 ha, contains as many as 58 families with 136 genera and 264 species. The ITCI plot 76-4, which is located in the middle slope and in a valley, is a poor plot, with only 198 species being recorded in an area of 1.65 ha.

Table 5 Number of families, genera and tree species (dbh 10 cm or more) at various sites in Kalimantan, Sabah, Sarawak and Penansular Malaysia

Site	Area (ha)	No. families	No. genera	No. species	References
Kalimantan					
Sekadau, West Kalimantan	0.6	37	71	106	Sidiyasa (1987)
Wanariset	0.51	35	76	117	van Valkenburg (1997)
Wanariset	1.6	45	122	239	Kartawinata *et al.* (1981)
Sungai Wain	**3.6**	**49**	**143**	**385**	
Lempake	1.6	44	125	209	Riswan (1987)
PT. ITCI (upper slope, Plot 76-3a)	0.5	31	62	104	van Valkenburg (1997)
PT. ITCI (middle slope/ Valley, plot 76-4)	1.65	44	108	198	van Valkenburg (1997)
Apo Kayan	1.12	58	136	264	van Valkenburg (1997)
Apo Kayan, Fagaceae plot	0.8	42	78	175	Bratawinata (1986)
Sabah					
Danum Valley*	4.0	-	-	242	Newbery *et al.* (1992)
Danum Valley*	4.0	-	-	247	Newbery *et al.* (1992)
Sarawak					
Gunung Mulu, alluvial plot	1.0	-	-	223	Proctor *et al.* (1983)
Gunung Mulu, diptero. plot	1.0	-	-	214	Proctor *et al.* (1983)
Peninsular Malaysia					
Pasoh	1.0	-	-	210	Kochummen *et al.* (1990)

* = Trees >12 in. (30.5 cm) girth at breast height.

Conclusion

1. Dipterocarps and most timber tree species in Kalimantan are found mainly in tropical lowland forest.
2. Tree species that are common in montane forests in East Kalimantan include *Shorea curtisii* ssp. *curtisii*, *Agathis endertii*, *Nageia wallichiana*, *Podocarpus neriifolius*, *Weinmannia borneensis*, *Adinandra* spp., *Lithocarpus* spp., *Tristaniopsis* sp. and *Eugenia* spp.
3. *Shorea balangeran* and *Cratoxylum glaucum* are the most common tree species found in kerangas forest.
4. Typical tree species that grow well in swampy areas are *Gonystylus bancanus*, *Alstonia pneumatophora*, *Alstonia spatulata*, *Cobretocarpus rotundatus*, *Dactylocladus* and *Lophopetalum javanicum* .
5. An indication of the forest structure of the Sungai Wain sample plot is given by a tree density of 535 trees/ha (representative for the Balikpapan-Samarinda area) and a basal area of 23.5 m2/ha, which is the lowest value compared to other forest sites that have been studied in Kalimantan.

6. The Sungai Wain forest is rather rich in tree species. In the sample plot of 3.6 ha, 385 tree species (dbh 10 cm or more) were recorded, belonging to 143 genera and 49 families.
7. The family of Euphorbiaceae is the most dominant family in the Sungai Wain sample plot with 47 species, followed by Lauraceae with 28 species, Myristicaceae with 27 species and Myrtaceae with 24 species.

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CONVERSION OF *IMPERATA CYLINDRICA* GRASSLAND INTO AN AGROFORESTRY SYSTEM THROUGH THE APPLICATION OF MYCORRHIZA AND SHADING BY TREES

Murniati

ABSTRACT

Imperata cylindrica Beauv. is a perennial grass, known as one of the most important weeds in tropical Asia. Most of the degraded land areas in Indonesia are invaded by the tenacious *Imperata* grass. Since *I. cylindrica* is a shade-intolerant plant, it can be suppressed by shading by trees or by herbaceous plants, which may be components of an agroforestry system. Research on suppressing *Imperata* grassland by growing mahogany (*Swietenia macrophylla* King) and various leguminous species in Boding Looping (West Java) has shown that populations of *I. cylindrica* significantly decreased after the mahogany plantation had reached the age of three years. In addition, several physical and chemical soil properties in the area improved as a result of tree planting. An agroforestry demonstration plot as a model for *Imperata* grassland rehabilitation on sloping dry land in Mangkaok village (South Kalimantan) has also given promising results. The growth of all tree species in the area is relatively good and yields of annual food crops are moderate. In most cases, the soils under *I. cylindrica* grasslands are acid and deficient in major nutrients. In order to support tree growth, mycorrhizal fungi may be applied as a biotic substitute for fertiliser. Research on the role of mycorrhizal fungi in supporting tree growth on *Imperata* grassland as well as to determine which tree species have an optimal shading effect is being carried out on farmland surrounding the Wanariset I Research Station, East Kalimantan.

I. INTRODUCTION

Imperata cylindrica, known as alang-alang in Indonesia, is a perennial grass and one of the most important weeds in the tropical Asia. The area under *I. cylindrica* in Southeast Asia is estimated to be 20 million hectares (Vanderbeldt in Turvey, 1994). In Indonesia the total area of grassland mainly dominated by *I.cylindrica*, is 10 million hectares, with a further 20 million hectares of land with bush/scrub cover associated with shifting cultivation (Tjitrosoedirdjo, 1993). According to Forestry Statistics of Indonesia 1996/1997, the total area of critical lands (usually dominated by *I. cylindrica* grass) was 12,517,632 ha of which 3,759,257 ha was inside forest land and the remaining 8,758,375 ha outside forest land.

Some of the *I. cylindrica* grasslands outside the forest land occur on transmigration areas, where most of the transmigration communities abandon their land (known as “lahan usaha 2”) after two to three harvests of food crops. Because of decreasing soil fertility followed by low productivity, they move to other pieces of land (usually forest land) to cultivate their food crops, a process of shifting cultivation. Other villagers create additional income through the practice of illegal cutting. The extensive shifting cultivation and illegal cutting practices are creating new *I. cylindrica* grasslands throughout the whole country, both inside and outside forest land.

Imperata cylindrica is very difficult to eradicate, because of its excellent propagation. It propagates itself generatively by seed and vegetatively by its extensive rhizome system.

Fortunately, it is a shade-intolerant plant. Shading of *I. cylindrica* results in the reduction of several growth parameters such as carbohydrate storage, rhizomes and tuber production (Macdicken *et al*, 1997). Therefore, shade-based control of *I. cylindrica* grass by using deep–rooted woody plants to compete with *I. cylindrica*, both above and below ground, may produce sufficient results.

Soil fertility under *I. cylindrica* grasslands is usually poor and deficient in major nutrients such as nitrogen and phosphorus. In the past, some farmers relied on government subsidy to pay for expensive chemical fertilisers, they now have to pay higher prices for these fertilisers themselves, since government subsidy has stopped. An alternative is now available through the use of a bio-fertiliser or a mycorrhizal fungi inoculate as a replacement for the expensive chemical fertilisers. The "plant roots-mycorrhizal fungi" association promotes the survival, growth and yield of plants by assisting in the absorption of nutrients and water from the soil and protecting the plants from root pathogens (Zarate, 1999).

An effective way is needed to suppress the *I. cylindrica* grasses in order to restore soil fertility and keep community lands productive, so that sufficient income is generated from the land. Control of *I. Cylindrica,* maintaining or even improving land productivity, will keep the people from entering the forest area and, at the same time, create possibilities for sustainable forest management.

This paper discusses some mixed land use systems for converting *I. cylindrica* grasslands into more productive lands, such as the use of N-fixing woody plants, the use of certain shade trees or cover crops and the application of mycorrhizal fungi in the form of bio-fertiliser.

II. THE ESTABLISHMENT OF AGROFORESTRY ON *I. CYLINDRICA* GRASSLANDS

Mixed land use was the rule in the tropics, as in the whole world, since time immemorial (Kippie, 1994). However, on degraded lands, traditional mixed land use is useless. Sound, sustainable, mixed systems depend on a living soil. New ecosystems must be built, step by step (Oldeman, 1983,1990), by methods like alley cropping with N-fixing woody plants (Budelman, 1991), hedgerow planting, terrace stabilisation by living tree roots or the application of bio-fertiliser (mycorrhizal fungi) (Zarate, 1999).

Agroforestry, as a mixed land use system generally accepted and advocated by the World Forestry Congress in Jakarta in 1978, combines the simultaneous production of agricultural crops and tree crops in a multi-storied vegetation structure. Agroforestry solves low production and land degradation problems and so contributes to the restoration of productivity and the creation of sustainability.

Research to convert critical *I. cylindrica* grasslands into more productive lands by means of an agroforestry system and the establishment of a demonstration plot is discussed below. The research was done in the Bojong Lopang region in West Java Province, while the demonstration plot was developed in Mangkaok Village in South Kalimantan Province.

A. Bojong Lopang research

In this study, mahogany (*Swietenia macrophylla)* was grown on *I. cylindrica* grassland. Since mahogany is a shade-tolerant species, it is able to compete with *I. cylindrica* grass in capturing enough solar radiation. The species is resistance to fire and can therefore be used for afforestation. The soil at the research site is a complex of oxisols, inceptisols and brown entisols. The topography is undulating, with slopes ranging between 20 and 25 %.

Six month-old mahogany seedlings in plastic bags were planted in field plots, at a spacing of 4 x 2 m. Leguminous species were planted densely between the mahogany rows for N-fixation. The species used were “lamtoro” (*Leucaena lecocephala*), “calliandra” (*Calliandra calothyrsus*) and “flemingia” (*Flemingia congesta*). These legumes were coppiced every 6 months and the biomass was laid between the mahogany and the legume rows. The mahogany growth was measured every six months until the plantation had reached the age of three years. *I. cylindrica* population and soil samples were taken before the mahogany planting and after the mahogany plantation had reached the age of three years.

The research results showed that populations of *I. cylindrica* decreased significantly from 208.2 stems/m^2 before the establishment of the plantation to 75.3 stems/m^2 after the mahogany plantation had reached the age of three years (a decrease of 64 % from the starting situation). The mahogany plantation also influenced the physical and chemical soil properties in the plantation area. The soil bulk density and soil organic matter content had improved as a result of tree planting. The soil bulk density decreased from 1.26 g/cc before planting the trees to 0.92 g/cc three years later. During the same period, soil carbon organic content increased from 4.93 % to 6.21 %. The soil properties that have improved are the phosphorus (P) and potassium (K) content, as well as the cation exchange capacity (CEC). However, the growth of the mahogany trees was not so good, the average height and diameter were 1.61 m and 3.20 cm, respectively, at the age of three years, 4.33 m and 5.42 cm at six years, and 5.57 m and 8.43 cm at eight years.

B. The Mangkaok demonstration plot

An agroforestry demonstration plot (demplot) was established at the end of 1993 in Mangkaok Village, South Kalimantan Province. It was an effort of the Forest and Nature Conservation Research and Development Centre (FNCRDC) in cooperation with the Asia Pacific Agroforestry Network (APAN) and the Riam Kanan Soil Conservation and Land Rehabilitation Sub Institute (now named the Forestry and Soil Conservation Service of Banjar). The demplot was established on farm land and managed by farmers who owned the land and is under supervision by a researcher and an extension worker.

The plot has been used as an extension object to demonstrate a farm in a sloping *I. cylindrica* grassland area. The soil in the demplot consists of a complex of ultisols, entisols and inceptisols. The topography varies from undulating to hilly, with a slope range of 20 – 40 %.

The demonstration plot used an “alley cropping” planting pattern that combines perennial tree crops and annual crops, together with terrace stabilisation by living tree roots of “lamtoro” (*Leucaena leucocephala*), “gamal” (*Gliricidia sepium*) and “calliandra” (*Calliandra calothyrsus*) for soil and water conservation. The N-fixing legumes were coppiced every four months. Part of the biomass was left in the plot and the other part was used for livestock fodder . Various tree species were planted in the demplot, including forest trees (acacia / *Acacia mangium and sengon / Paraserianthes falcataria*), fruit trees / multipurpose trees (durian/D*urio zibethinus*, mango/*Mangifera indica*, petai/*Parkia speciosa*, rambutan/*Nephelium lappaceum* and coconut/*Cocos nucifera*). Perennial shade-tolerant crops include coffee/*Coffea sp.*, ginger/*Zingiber officinale* and “kencur”/*Kaempferia galanga*. Annual food crops planted between the perennials include rice/*Oriza sativa*, maize/*Zea mays*, groundnut/*Arachis hypogaea* and cassava/*Manihot esculenta*.

Forest trees, fruit trees and terrace stabiliser plants were planted when the demplot was first established. Annual food crops were cultivated during the first three years, while shade-tolerant crops were planted in the third and fourth years. Acacia was grown in monoculture at the top of the hill, while “sengon” and fruit trees were mixed planted on the slope. Annual food crops and shade-tolerant crops grow as inter-crops between the “sengon” and the fruit tree rows.

In general, until the fourth year, the growth of the trees and crops was relatively good. The average height and diameter of *A. mangium* and *P. falcataria* were 8.10 m and 12.38 cm and 13.80 m and 17.27 cm, respectively. The vegetative growth of the fruit trees was considered sufficient, but except for the “rambutan” trees, they did not produce fruits until the fourth year,. Among the fruit trees, “petai”, a N-fixing species, showed the best vegetative growth; the height and stem diameter reached 5.20 m and 7.01 cm, respectively. The production of annual food crops was only moderate. The dry field rice yielded 2.6 tons of dry grain/ha/season, maize produced 2.9 tons of dry grain/ha/ season, while the groundnut production was 1.1 tons/ha/season. The biomass production of terrace stabiliser plants varied. The highest biomass production was given by “calliandra”, i.e. 3.68 tons dry weigh/ha/year, while “lamtoro” had an intermediate level production of 1.78 tons/ha/year. The lowest biomass producer was “gamal” with 1.21 tons/ha/year. On the basis of the N-content of the biomass of each species (“calliandra” 2.7%; “lamtoro” 3.0% and “gamal” 2.9%), “calliandra” can supply 99.27, “lamtoro” 53.30 and “gamal” 34.95 kg N/ha/year, either into the soil or as livestock fodder. *Imperata cylindrica* grass hardly grew in the second year after the establishment of the demplot. By that time, the crowns of trees and crops covered most of the land surface. After four years, an agroforestry demonstration plot with a multi-storied crown had been created. The vegetation structure consisted of four canopy layers: the upper layer (± 15 m high) was dominated by a forest tree canopy, the second layer (± 5 m high) was occupied by fruit trees/multipurpose tree crowns, the third layer (2-3 m high) was filled by coffee branches and banana leaves, while the lowest layer (< 1.5 m high) was occupied by annual crops or broad-leaved weeds such as *Eupatorium odoratum.* The farmers' income from the agroforestry system varied, depending on the area of the farmland. The average annual income during the first, second and third years was US $ 487.5, 669.2 and 380.4, respectively.

III. DISCUSSION

The establishment of agroforestry on *I. cylindrica* grassland at two different sites produced satisfactory results. The *I. cylindrica* population decreased sharply. The shading effect of tree crowns (both forest trees and N-fixing trees) suppressed the growth of *I. cylindrica* grass. Maintenance of the tree plantation, particularly during the first years after planting, resulted in considerable vegetative tree growth, thus increasing the land cover/shading effect , while the suppression of *I. cylindrica* grass was also increased and accelerated. The best result was obtained at the Mangkaok site, where *I. cylindrica* grass suppression occurred in the shortest period (± 2 years). This was caused by the land preparation and planting activities and the planting of annual food crops, which resulted in a denser and wider land cover.

On both sites, the establishment of the agroforestry system, using several legumes species as N-fixing plants, played an important role in the improvement of soil fertility. Biomass production through the periodical pruning of legumes (left behind in the plot) has ameliorated the physical and chemical soil properties, particularly soil organic matter and soil structure. In addition, part of the legumes' biomass was used as animal fodder. The role of N-fixing trees can also replaced by leguminous cover crops, such as *Pueraria javanica.* There are several advantages in using these leguminous cover crops to suppress *I. cylindrica* grass, for example, faster growth, spread out over the whole site and vigorous twining and climbing stems (Macdicken, 1997).

As stated above, not only forest trees, fruit trees, and N-fixing legumes were grown in the agroforestry demonstration plot in Mangkaok, but also annual food crops. In this demplot, several farmers participated in managing the tree and food crops. They formed a farmers group as a platform for communication and discussion. During the first three years, the farmers obtained significant income generated by the annual food crops (rice and second crops). The highest income was achieved in the second year. After that, the income decreased sharply in the third year. This was caused by a decrease in annual food crop production. Since by now tree crowns created a closed canopy, only limited solar radiation reached the lower vegetation layer, while the tree crops (fruit trees and coffee) had not yet produced fruits. The farmers' income is expected to increase soon in the fourth year and later, when the fruit trees or shade tolerant crops start to yield.

IV. ONGOING RESEARCH

Conversion of *I. cylindrica* grassland through the establishment of agroforestry depends on the shading ability of trees and herbaceous cover to suppress the grass. The shading effect of trees depends on branching models and crown shapes, which can be modelled using geometrical parameters (Oldeman, 1998). The effect can be assessed through the leaf area index, crown volume and light intensity on the ground. Accelerating the vegetative growth can intensify the shading capacity of trees. The application of mycorrhiza as a biotic substitute for fertiliser is an alternative technology for promoting the vegetative growth of trees.

Research into the conversion of *I. cylindrica* grassland into agroforestry through the application of mycorrhiza and using the shading ability of trees was started at the beginning of this year. The research is being done on farmland in the area surrounding the Wanariset I Research Station, East Kalimantan Province.
The research objectives are:

- To study the role of mycorrhizal fungi in supporting tree growth on *I. cylindrica* grassland
- To determine which tree species have an optimal shading effect for suppressing the grass.

The hypotheses of the research are:

- The growth of trees in an *I. cylindrica* environment will be supported through symbiosis with mycorrhizal fungi; rapid tree growth can suppress *I. cylindrica* grass.
- Trees with the highest leaf area index and the largest crown volume will have the optimal shading effect for suppressing *I cylindrica* grass.

The research consists of two parts. The first part is being conducted in a nursery and the second part in field plots.

Nursery research.
The plant production in the nursery was set up according to a completely random design in a factorial experiment. There are two factors :

1. Tree species (4 species: *Swietenia macrophylla, Peronema canessen, Aleurites molucana, and Artocarpus artilis*).
2. Mycorrhizae treatments (with and without mycorrhizae) The source of mycorrhizal fungi is "Micofer", a kind of mycorrhiza inoculant containing four species of endomycorrhizal fungi, i.e. *Glomus manihotis, Gigaspora margareta, Acaulaspora sp.* and *Scultelespora sp*. Seedling growth was monitored by observing and measuring the following variables: height and stem diameter, dry weight of the total biomass and shoot-root ratio.

Field research
Experimental plots are set up according to a split plot design (Steel and Torry, 1991).
In the main plots the mycorrhizae treatments consist of:

- seedlings with mycorrhizal fungi
- seedlings without mycorrhizal fungi

In the sub-plots the application of two factors:

- suppliers of shade (4 tree species : *Swietenia macrophylla, Peronema canessen, Aleurites moluccana, and Artocarpus artilis)*
- *I. cylindrica* treatments (herbicide, pressing and ploughing).

As an initial treatment, all the plots are planted with a leguminous cover crop (*Pueraria javanica*) during the first six months, while annual crops will be planted by the farmer after initial treatment has been finished.

The parameters used to observe and measure the development are:

- tree growth (height, stem diameter and survival percentage)
- shading capacity of various tree species, according to leaf area index, crown volume and light intensity on the ground
- *I. cylindrica* population and biomass
- growth and yield of crops
- leaf area index and biomass of cover crops
- soil properties (chemical, physical and profile)
- rain fall during the research
- architectural sketches of the trees
- soil micro-organisms: species and population
- root tissue analysis

V. CONCLUSION

The establishment of agroforestry on *I. cylindrica* grassland at two different sites showed that marginal grassland areas can be converted into more productive land by the implementation of several mixed land use technologies to build a new ecosystem and to improve the living soil. The technologies should include N-fixing plants, should consider the shading capacity of trees, should include soil and water conservation methods and should apply mycorrhiza as biotic substitute for fertilisers.

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RADAR TREE MAPPING AND FIEPLP METHODOLOGY TO SUPPORT SUSTAINABLE FOREST MANAGEMENT

Kemal U. Prakoso, Bambang K. Suryokusumo and Dirk H. Hoekman

ABSTRACT

High resolution interferometric synthetic aperture radar (InSAR) images collected by the Dornier system during the ESA-MOF INDREX-96 campaign are used to produce 3-D tree maps showing tree position, projected tree crown boundaries and tree height. These maps are made using single track C-band data, single track X-band data, and dual (orthogonal) track C-band data. The quality of the different approaches can be compared qualitatively using an extensive database of ground observations, in particular, by comparison with a 7.2 ha FIEPLP (Forest Inventory & End Product Linking Program) plot created especially for validation purposes. FIEPLP tree maps and radar tree maps are complementary. In future operations, radar tree maps can facilitate fieldwork for the production of terrestrially measured FIEPLP field tree maps and, at the same time, can give additional reference and other information. The real value of radar tree maps is that they can be made quickly and cheaply for all the areas needed. They may give sufficient information for enforcing legislation for sustainable forest management. Where more detail is needed, more detailed information is added from FIEPLP field surveys.

The availability of a robust automated interpretation procedure for such radar data is of particular interest, because of the enormous data volumes to be handled in short periods in order to achieve sustainable national forest management. The possibilities for the use of INSAR high spatial resolution (1.5m) as a tool to observe tree crown and tree height in tropical rain forest - allowing estimation of timber volume for individual trees on the basis of allometric relations/equations - need more research. This paper reports on the validation and demonstration of the use of the InSAR tree map systems. It also gives an insight into the potential use of FIEPLP and radar image processing tools in a tropical rain forest application in Indonesia.

I. INTRODUCTION

In 1996, the Indonesian Radar Experiment (INDREX) campaign was conducted under the auspices of the Indonesian Ministry of Forestry (MOF) and the European Space Agency (ESA) (Attema *et al*, 1996). The Dornier SAR system collected data in several modes over Dipterocarp tropical rain forest test sites in the province of East-Kalimantan. A 100 x 100 km area, comprising several forest concessions and large converted areas (alang-alang/grassland, rice field, pastures etc) was selected near Balikpapan. It is also the Tropenbos study site for which MOF and the Association Concession Holder (APHI), among others, provide major support. The study makes use of existing techniques for SAR Interferometric analysis and investigates how these techniques can be implemented for tropical rain forest in Indonesia. Severe cloud cover limits the use of aerial photography, which is currently applied on a routine basis to extract information from the forest. Interferometric techniques have a potential to yield three-dimensional information by using the phase as an additional information source derived from the complex SAR data.

A main topic of the study is how to best use the possibilities of using Interferometric SAR (InSAR) as a tool for observing crown and tree height in tropical rain forests and for estimating timber volume. Several possibilities of recognising individual trees in high spatial resolution (1.5 m) images will be investigated. The volume of individual trees can be estimated from allometric relations using tree crown projections along with the validation of the tree mapping methodology. The quality of the different approaches can be compared quantitatively using an extensive database of ground observations, in particular, by comparison with a 7.2 ha FIEPLP (Forest Inventory & End Product Linking Program) plot created especially for validation purposes.

This paper describes and evaluates ideas on how to introduce new InSAR techniques for automatic tree map generation and gives an insight into the potential use of radar image processing tools. This will be useful for supporting the Indonesian Government in managing permanent forestland to achieve one or more clearly specified management objectives. These include the production of a continuous flow of desired forest products and services without undue reduction of the forest’s inherent values and future productivity and without undue undesirable effects on the physical and social environment (FAO, 1997; van der Sanden, 1997)

II. ACROSS-TRACK SAR INTERFEROMETRY

A promising technique for the extraction of information from remote sensing data is that of Interferometry Synthetic Aperture Radar (SAR), or InSAR. Using the InSAR technique, it is possible to produce detailed and accurate three-dimensional (3-D) relief maps of the Earth's surface directly from SAR image data.

The principle of the radar technique is that each pixel of a radar image contains information on the phase of the back-scattered radar echo from the underlying surface. By utilising the geometry provided by two marginally displaced, coherent observations of the surface, phase difference between the two observations can be related to surface height. Two antennas can detect the phase differences at the same time. The system is called single pass interferometry. The information provided can be used not only to determine the relative elevation of the ground surface (Digital Surface Model DSM) but also of other objects on the surface, e.g. like Digital Elevation model DEM).

The across-track system of interferometry is employed only on airborne systems, as it requires two SAR antennas to be mounted simultaneously on the platform, separated by a baseline (B) perpendicular to the flight line. The geometry illustrated in Figure 1 shows the position of the two antennas mounted on an aircraft. The phase difference is given in the equation below.

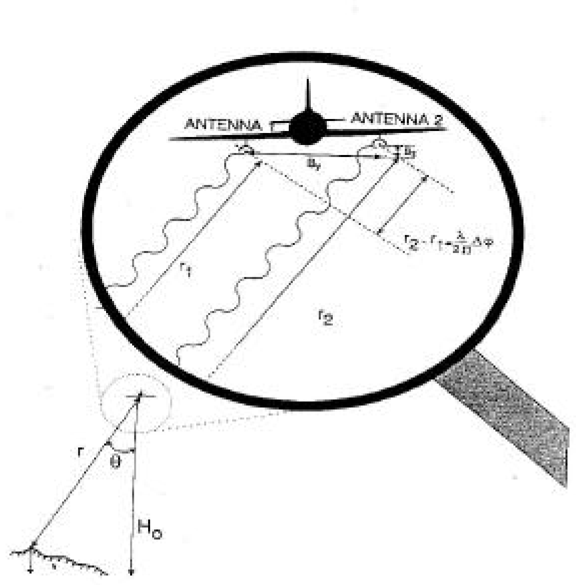

Figure 1 Across-track InSAR concept (van der Kooij *et al.*, 1995)

The terrain height is related to the flying height H, the slant range r and the look angle by:

$$\Delta f = \frac{2\Pi}{l}(By\sin q + Bz\cos q)$$

$$h = H_0 - r\cos q$$

There are however some complications to interferometric imaging. One of them is that the phase difference increases linearly with the swath (near to far end of an image line) (Balmer and Just, 1995). The phase differences are measured with an ambiguity of 2 pi. Plotting the phase difference against the range distance therefore results in a saw-tooth shaped graph for flat terrain. This causes interferometric fringe lines on a raw interferogram. Terrain structure results in different fringe patterns. This deformation of linear fringes carries information on terrain elevation.

Another complication is the size of the resolution cells. The resolution cells of the interferometric images are quite large relative to the scatterers (leaves and branches). Therefore the resolution cell signals received are the result of scattering from many scatters. This resultant signal is very sensitive to changes in microstructure and viewing.

The main scatterers for X- and C-band interferometry of a forest canopy are small compared to the size of a resolution cell. The different heights of the scatterers make it difficult to determine the location from which the signal is re–radiated and thus from which point the actual height is determined. The penetration into canopy and, therefore, to the point from which the actual height is determined, will depend on leaf and branch density and on the wavelength. Since X- and C-band radiation is mainly scattered back from the canopy surface, heights will also mainly be related to the canopy surface. In an open canopy (low leaf density) the radiation will penetrate deeper into the tree crowns, and leaves and branches in the crowns will make a bigger contribution to the back scatter, resulting in the height being determined from a different point (Hoekman, 1990).

III. RADAR TREE MAP CONCEPT

Using normal back scatter intensity images, there may be radar shadow and layover effects when trees with different heights are located at the same range distance. This results in the tree crowns appearing imaged on top of each another. Using interferometric images this situation can be detected through the measurement of phase coherence. Loss of coherence is indicative of layover and can be modelled as a function of vegetation height differences. The larger the height differences in a certain range cell, the lower the observed coherence. Analysis has shown that the interferometrically derived height can give a substantial underestimation of the true height while, at the same time, there can be large displacement errors for individual trees. This model will be tested and validated for the automated production of tree maps from InSAR data.

Tree position on high resolution InSAR data has also been investigated. Some problems inherent in INSAR techniques, such as shadow and layover can be solved by application of the Van Cittert-Zernike theorem and models (Hoekman and Varekamp, 1998).

IV. TECHNIQUES FOR INTERFEROMETRIC SAR TREE MAP PROCESSING

The data-processing task consists of several parts, shown in Figure 2. The first step of the interferometric processing was a precise co-registration of the image pairs of the individual passes to a sub-pixel level, after which a phase difference and coherence image was computed. After phase-coherent pass summation, the multi-look phase difference image was unwrapped, using the coherence image to mask the shadow areas. For height generation, the unwrapped phases are converted to height, using geometry given by the reference track which was used during the InSAR processing.

After obtaining unwrapped phase data, the next step is to fine tune the tree crowns boundaries using objective methods (Varekamp and Hoekman, 1998; 1999), in which both edge and regional information are used in a model based on phase difference segmentation. Limiting the number of Fourier harmonics to k=3 seems appropriate for representing a tree crown boundary.

Since optimal boundaries are in range coordinate r and azimuth coordinate x, correction to these data is still needed. The displacements can be corrected by application of the Van Cittert-Zernike theorem (Hoekman and Varekamp, 1998).

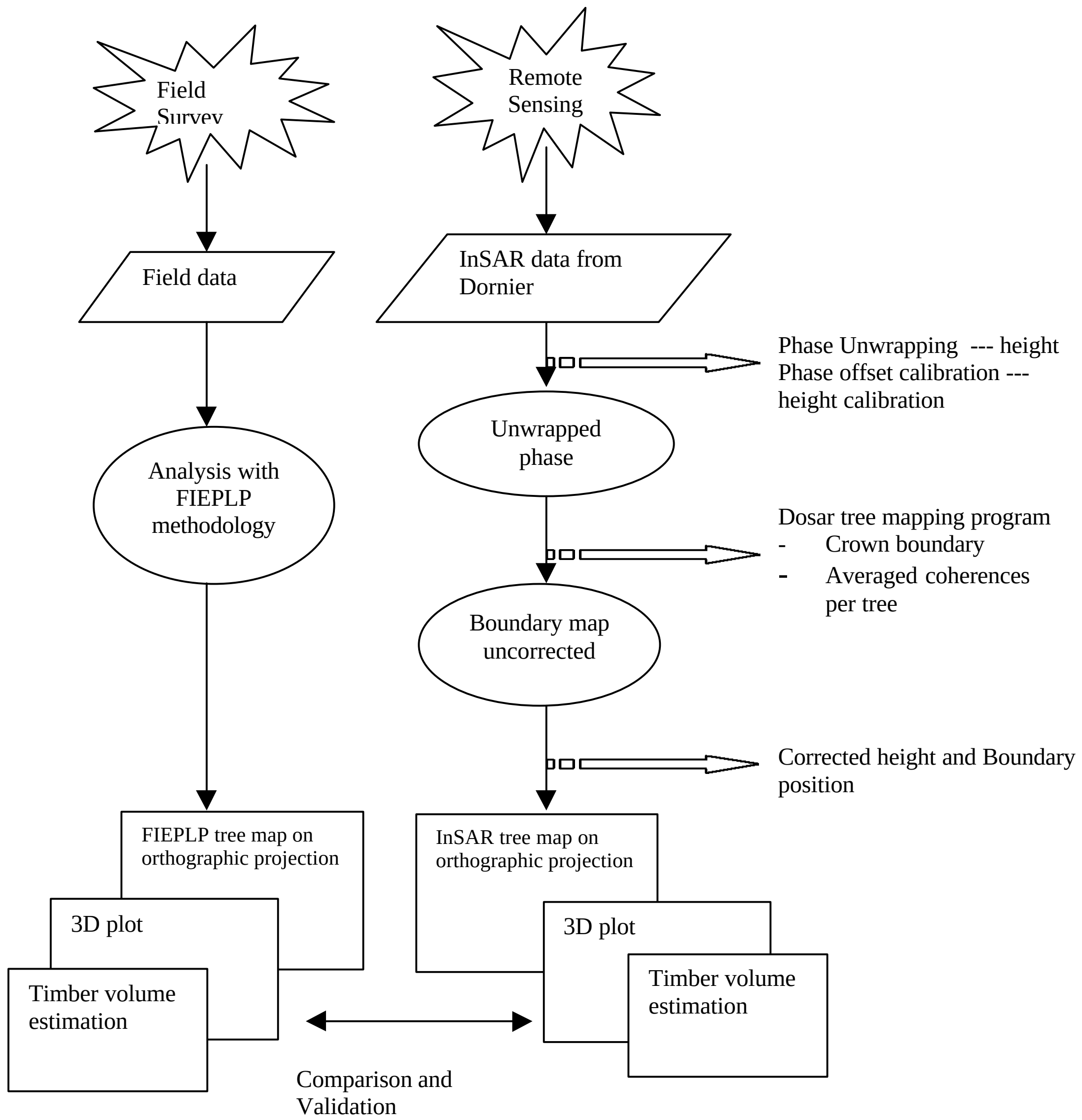

Figure 2 Processing chain for generation of INSAR tree map and field survey

The final output of InSAR tree mapping is a map with tree crown boundaries in orthographic projection in a bitmap or postscript file and showing coordinates in ground range and azimuth direction with the same orientation as the radar image. To obtain a better qualitative assessment, a 3-D visualisation of tree crowns will be shown on the computer screen just like the way radar sensor look at the target. The output from InSAR tree mapping can be compared and validated with field survey data. Parameters used for this purpose are crown outline description (aerial photographs) and spectral signature (multi-spectral images). Tree crown delineation from aerial (stereo) photographs is time-consuming and expensive. A robust algorithm using Fourier parameterised deformable templates can be used to construct and to locate a tree crown boundary (Varekamp and Hoekman, 1998; 1999).

To run the software several data are needed, including: intensity (*.pwr), complex coherence (*.int), Dornier unwrapped phase (derived from filtered data (*.unw)) and unwrapped phase (done on unfiltered data (*.dat)). The graphical user interface of the current version (Figure 3) shows (**1**) the intensity of a full track overview image, (**2**) a subset giving the combination of height and intensity image.

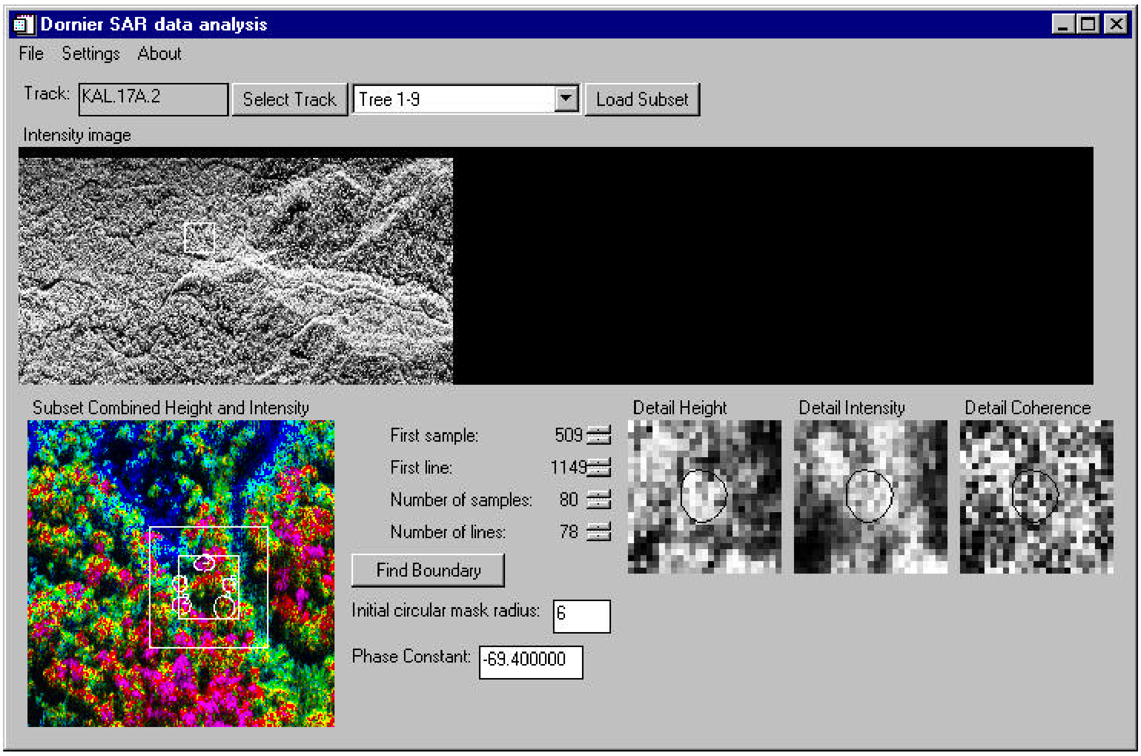

Figure 3 Graphical user interface of InSAR tree mapping data

After the selection of a desired sub-set, the user can select an area within a sub-set (**2**). This area will be used to detect tree crowns by means of "click and drag" within a rectangle, starting from upper left and dragging to lower right. Start locations of the tree crowns will be drawn within the inner square. The user can manually adapt this area by changing the sample and line number. The user can also change the initial circular mask radius and the phase constant. When the right area and parameters are set, the boundary finding can be started by pressing the button 'Find Boundary'.

The user can view the process for every boundary in the image window (**3a**) for detail height, (**3b**) for detail intensity and (**3c**) for detail coherence. When processing has finished and all the boundaries have been found, the user can save the result in a bitmap file or as postscript. A text file containing parameters and even tree-dimensional visualisation can be shown on screen.

IV. AREA COVERAGE AND GROUND DATA COLLECTION APPROACH

The study fits into the framework of the INDREX (INDonesia Radar Experiment) campaign carried out in East-Kalimantan province. The area has a tropical seasonal climate and comprises different intact primary forest types and logged-over areas that have been subject to selective industrial logging. This area is also characterised by the presence of secondary forests and a variety of non-forest cover types such as pastures, agricultural crops, burned areas and bare soils.

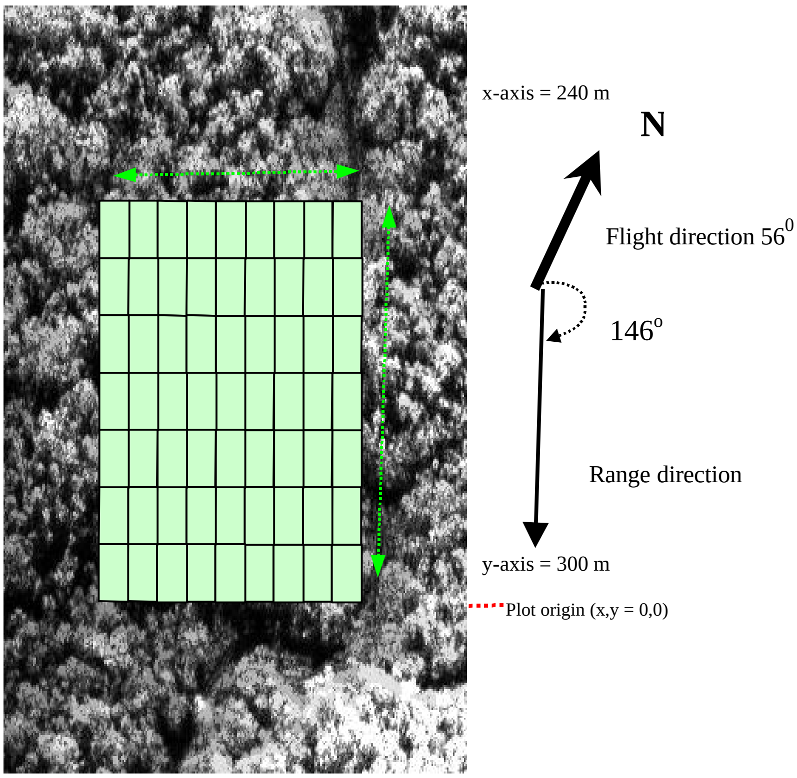

Figure 4 InSAR C- Band Image overlay with grid field map and Plot orientation, Dimensions and origin of 300 x 240m.

The study area (Figure 4) was imaged using the high resolution C– and X-band airborne Dornier SAR. This area contains a sample plot of 7.2 ha (300 x 240 m) in which terrestrial data were recorded using the FIEPLP methodology. In the 7.2 ha plot, the following data were collected for all trees with a diameter at breast height of 20 cm or more (DBH > 20 cm):

- Tree stem position co-ordinates
- Extreme (boundary) co-ordinates from tree crown in eight directions
- Height of the tree top
- Height of the periphery
- Height of the bottom of the crown
- DBH (diameter at 1.3 meter height)

For accurate measurements of tree stem co-ordinates, a grid was made by placing wooden poles 10 metres apart, making corrections for elevation differences (this was done by Wanariset technicians). The terrain heights of these grid points were measured relative to one of the grid points.

The tree stem coordinates in the y-direction were measured using a measuring tape placed between the wooden poles. The distances in the x-direction where determined by measuring the distance to the tape using a Haglof Distance Meter. This device can measure distances up to 10 m under normal conditions and up to 20 m in ideal conditions with an accuracy of +/- 1%.

The tree crown coordinates were determined by measuring the distances from the stem to the four extreme distances of the crown, parallel to the x and y-axes. Haglof distance meters measured eight directions of three crown coordinates.

Tree heights were measured relative to the stem base using a Suunto Clinometer. To obtain an accurate height measurement, the distance from the observer to the tree should be at least half the tree height, while the most accurate measurements are obtained when the distance from the observer to the tree is equal to the tree height. Object related errors can occur in dense stands, where the top or stem base is not clearly visible. Height measurements of hardwoods can yield overestimates, because branches can be mistaken for the tree top. Another error occurs when the tree is leaning either towards or away from the observer.

Measurements of three heights require skill, which can be obtained by training. Observer related errors occur, for example, because of bad vision, faulty instrument operation and incorrect technique when taking readings.

The diameters of trees are measured mainly in order to derive the cross-section area of the tree. The tree diameters were measured at a height of 1.3-m (DBH), using diameter tape. Errors can occur here when the tape is not placed exactly around the measurement plane, perpendicular to the stem. This causes an overestimation of the DBH, which is in the order of 0.5% for a tilting angle of 5%, other errors occur when cross-sections are not circular or there are stems with buttresses, resulting in an overestimation of the basal area.

V. PRELIMINARY RESULT

From the 1064 trees measured in the field the data of only 872 trees was processed, the rest of the trees were dead. Figure 5 (a) shows a perspective view from the same direction as the radar look direction. It was compared to interferometric height, which is calculated using the tree plot program developed in IDL, which generates, among other things, three-dimensional images from different viewing angles.

A qualitative assessment can show the quality of the InSAR tree map algorithm. Figure 5 (b) shows C- band InSAR data, (c) shows dual (orthogonal) track C-band InSAR data, (d) shows the X- band. InSAR data give a higher number of tree crowns, which may be caused by lower radar penetration on top of the crown canopy. The interferometric images with 1.5-m resolution at 6 looks show a 3-D perspective view of the canopy from the radar look direction. This will give a much better perception of individual trees and their locations. This can be very useful when one wants to know which trees should be visible on the radar image.

Turning to the use of X and C-band data (C-band penetrates deeper into the crown canopy), the flying height and the look angle, the result from the radar images clearly shows that only around 64 emergent trees can be detected well. Vegetation causes a higher back scatter than other land cover (bare soil, logging roads) and therefore appears whiter on the image. Individual tree crowns, especially the ones that dominate the canopy, can be delineated, because the edges and the area around the crown appear darker than the top of the crown.

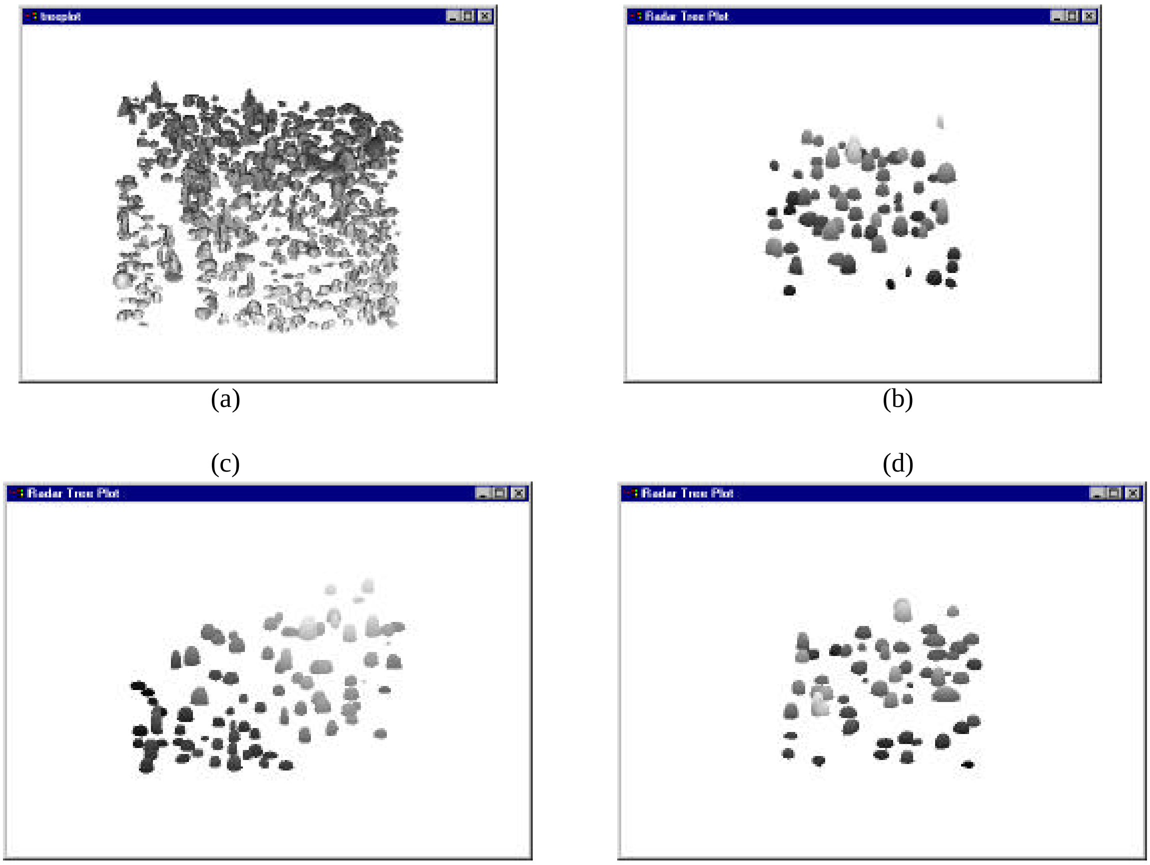

Figure 5 (a) shows the field tree map data, (b) shows C-band InSAR data, (c) shows C-band data with a look direction perpendicular to (b), and (d) shows X-band. The interferometric images with 1.5-m resolution at 6 looks show a 3-dimensional view of the canopy from the radar look direction.

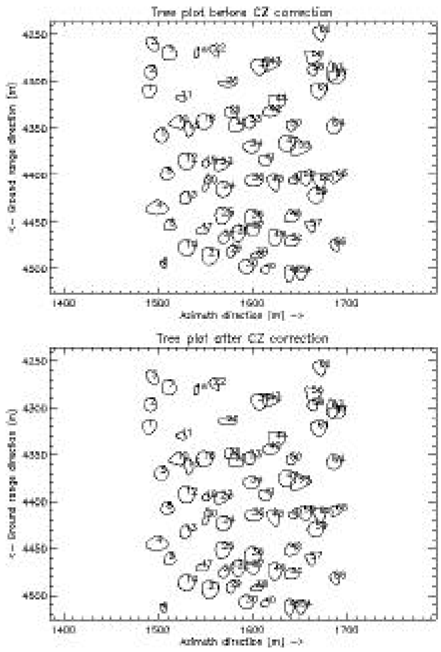

Figure 6 Shows the orthographic projection of InSAR tree crowns before and after correction

Figure 6 shows the orthographic projection of the radar tree map before and after correction. The number of tree crowns in the radar tree map is less, which is caused by the fact that the field tree map is measured from below and radar measures from above. In this case, the radar look angle is 55^0 and flying height is around 3228 m. To increase the number of trees, the dimension of the initial circular mask radius number has to be decreased. The smaller radius will produce more trees than the bigger one, but it will reduce the accuracy.

If the radar can detect and distinguish a single tree very clearly, the radar dimensions of each emergent tree crown will be similar to the measurements in the field. Where there is a group of trees of the same height, the radar will detect one crown boundary, but if the heights are different, the radar will detect only the emergent trees.

When the crowns are not in the upper part of the canopy, and thus in most cases obscured by other crowns, they are not imaged by the radar. The crowns are also not imaged when they are in the radar shadow of other tree crowns. When tree crowns are in the upper part of the canopy, but are merged together, it is very difficult to separate them on the image. This is often the case with crowns in the second highest layer of the canopy, because of competition between trees to reach the highest layer. It could be the effect of layover and foreshortening if the crowns are in a line perpendicular to the flight line. Comparing the image with the ground data map where several crowns are merged together is useless, as visual interpretation does not reveal any individual crown.

VI. CONCLUSIONS AND RECOMMENDATIONS

The results of this study demonstrate the capabilities of InSAR tree map for facilitating forest assessment and inventory activities in Indonesia. Information on terrain, forest and tree characteristics is needed to enforce national legislation for sustainable forest management or to verify implementation of guidelines for sustainable forest management as proposed by the International Tropical Timber Organization (ITTO). An InSAR tree map could support and complement fieldwork and the application of aerial photography to provide data at the tree level.

InSAR tree mapping using X and C-band 1.5m resolution is capable of detecting and delineating 64 individual tree crowns out of a total of 1064 trees measured in the field. The condition is that these individual trees have distinctive characteristics which clearly separate them from other trees. The three-years time gap between data acquisition and fieldwork contributed to the difficulty in separating individual trees. Problems are caused by crown irregularities, that is, what can be seen as a treetop and what can be seen as a tree crown edges. Several fast growing pioneer trees, mainly located along the main logging road, can cause interpretation or comparison problems between a radar tree map and field tree map.

For further progress into the study of the relations between InSAR data and forest parameters, theoretical modelling and robust algorithm for automatic InSAR tree map production need to be done and tested within several other study areas and making use of other parameters. Research should comprise extensive processing of different areas in the interferometric mode as well as specific verifications and validations of the results in a quantitative and qualitative way.

The results presented in this paper have clearly shown that a systematic investigation in the field of quality assessment of InSAR tree map capability data is necessary and feasible. However, many aspects related to this topic still require more research. The results have also indicated that further research on these lines would be most rewarding in terms of user requirements to produce digital tree maps by means of high resolution InSAR at an operational level.

Acknowledgement
We thank MoFEC and Tropenbos for help in realising this research and the MOF-Tropenbos Kalimantan project for logistic support, PT. Mapindo Parama. We thank Martin Vissers, Chris Varekamp, Anjo de Jong, Muljanto Nugroho, Ruandha Sugardiman and Eric van Valkengoed for assistance and ideas.

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TOWARDS AN ECOLOGY-BASED STRATEGY FOR THE REFORESTATION OF *IMPERATA CYLINDRICA* GRASSLANDS IN EAST KALIMANTAN

G. Wim Tolkamp, Aldrianto Priadjati and Riskan Effendi

ABSTRACT

Unproductive *Imperata cylindrica* Beauv. grasslands cover more than 20 million hectares in Indonesia. Urgent rehabilitation is needed to prevent the worsening of this ecological and economical disaster. An ecology-based strategy to accelerate the reforestation of grassland towards a dipterocarp-dominated plantation, in which natural regeneration occurs, was developed in combination with fire control measures. The first step in the implementation of this strategy, the establishment of a pioneer plantation, started in 1996. The results so far indicate that essential prerequisites for success are the selection of both pioneer and dipterocarp species and the application of appropriate fertilisers. *Peronema canescens* is a local pioneer species which is fire tolerant and economically attractive to local people. It therefore seems to be a suitable species for the first phase of grassland reforestation in Indonesia. Hardwood cuttings of *P. canescens* were collected from 12 locations in South and East Kalimantan and propagated on a large scale. Direct planting of unrooted branch cuttings in grassland is technically feasible. The species was interplanted in 1999 with *Shorea leprosula*. This kind of plantation may serve as a buffer between existing natural forests and villages with agricultural areas and may also diminish fire risk and thus decrease the establishment of new grasslands in those areas. An introduction of these multi-species plantations (farmers' forests) is proposed. Employing this ecology-based strategy, 30 hectares of *I. cylindrica* grasslands were reforested with a mixture of species during 1998 and 1999. Land tenure issues, poor infrastructure and transportation problems affected the execution of these activities. Feasibility studies and more integrated research in a comprehensive programme (experiments performed by concessionaires, mining companies and farmers, but supervised by researchers) are suggested. Collaboration between Asian institutions and projects in Indonesia is proposed.

INTRODUCTION

Shrinking forests, expanding grasslands

In Indonesia more than 20 million hectares are covered with unproductive *Imperata cylindrica* Beauv. grasslands, generated through human influences and fires (ITTO, 1990). Natural regeneration of these grasslands into forest does not occur on a large scale in current land use practices.Large-scale reforestation activities with exotic tree species were therefore undertaken with varying results. Successful reforestation of these grasslands is effective only if it is ecologically and technically possible, economically feasible, and socially and politically realistic (Garrity, 1997). After the fierce fires in 1997/98, the area of grasslands increased dramatically, especially in Kalimantan. The need for rehabilitation is therefore very urgent and quick action is required. There is a preference for indigenous species, since these species are expected to fit better into the ecosystem than exotic species.There is thus an increased need for proper information about suitable native species, which is not yet available. Suitable species have to meet several criteria in order to be useful for the reforestation of these critical lands. Only a few local pioneer species have been tested on a small scale in Kalimantan (Otsano *et al*., 1997).

Hypothesis
The introduction of indigenous pioneer - dipterocarp - plantations offers an alternative to reforestation of *I. cylindrica* grasslands with exotic tree species plantations and slash-and burn agriculture in non-populated areas. These heterogeneous forest plantations, which contain characteristics of natural forest, may have multiple functions, i.e. buffer zones, conservation of biodiversity, water regulation, soil protection, source of timber and non-timber forest products to alleviate the poverty of local communities.

The following working hypothesis has guided the research: A pioneer – dipterocarp - plantation is increasingly more sustainable when it has a species composition more similar to that of the original local rain forest, in contrast to monocultures of exotic tree species.

Objectives and research activities
The hypothesis and the available knowledge, including the results of the first phases of the Ministry of Forestry-Tropenbos Kalimantan Programme, led in 1996 to the implementation of a study, which forms the subject of this paper (Tolkamp, 1996 a,b). The following main and secondary objectives were formulated.

***The long term objective**:*
To develop an ecology-based strategy to accelerate the succession of *I. cylindrica* grassland into a multifunctional plantation.

The short term objectives:
1. To select both pioneer and dipterocarp species for their suitability for competing with grasses;
2. To study the effect of fertilisers on succession;
3. To domesticate promising species.

The following activities were undertaken from 1996 onwards:
1. Selection of species:
- ➢ The establishment of 4 elimination experiments in 1996 and 1998 to select local pioneer species;
- ➢ In 1995 two dipterocarp species experiments were established under a canopy of residual forest and in open *I. cylindrica* grassland.
2. A study on the effect of fertilisers:
- ➢ A fertiliser experiment with 4 pioneer species to accelerate "succession" was established in *I. cylindrica* grassland in 1996.
3. Domestication of promising species:
- ➢ Collection of more than 100,000 cuttings from 12 natural populations of the fire-tolerant and economically attractive species *P. canescens* in South and East Kalimantan (1998) and seeds from two mother trees. (Tolkamp, 1998)
- ➢ Improvement of vegetative propagation techniques for *P. canescens* in order to ensure a constant supply of plant material of known origin (1998).
- ➢ The establishment in 1998 of an experiment of direct planting of unrooted and *rooted P. canescens* cuttings in *I. Cylindrica*-dominated grassland.
- ➢ The establishment in 1999 of an experiment on the influence of shading of *Shorea leprosula* by *P. canescens* with the aim of contributing to the study on water-stress physiology in this

dipterocarp species

Thirty hectares of *I. cylindrica* grasslands were reforested with a mixture of pioneer and local fruit tree species during 1998 and 1999. Land tenure issues, poor infrastructure and transport problems delayed the execution of these activities.
The fires of 1997-1998 basically destroyed all the field experiments established until then, and the species elimination experiments, in particular, had to be restarted.

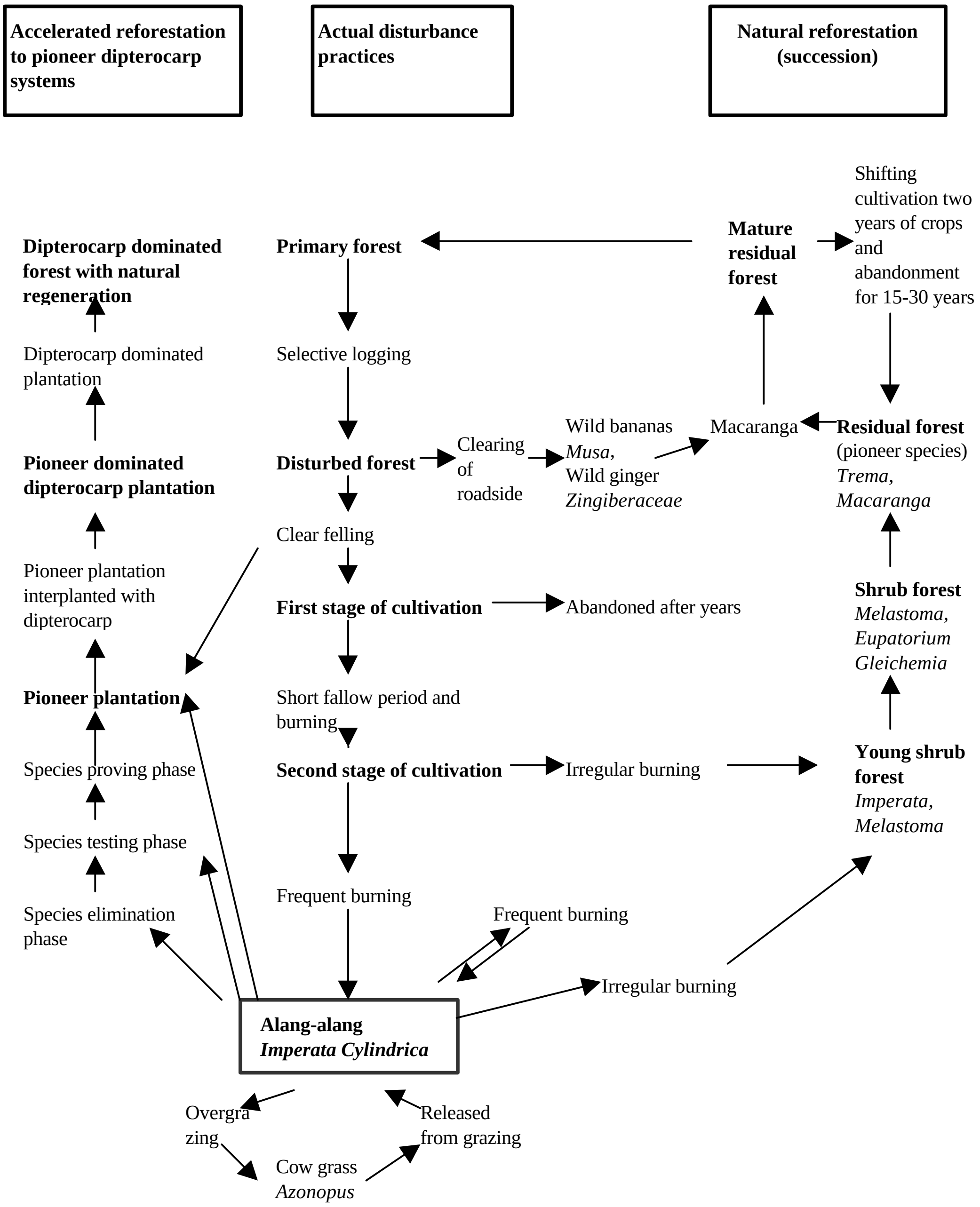


Figure 1 Natural and accelerated regeneration of *I. cylindrica* grasslands (partly adapted, MacKinnon, 1996)

BASIC CONSIDERATIONS

Imperata cylindrica grasslands

The disastrous large-scale tropical rain forest degeneration process and the opposite process of forest regeneration, the latter unfortunately only allowed to develop in relatively small areas, has been described extensively. Kathy MacKinnon et al. (1996) did this specifically in the excellent handbook "The Ecology of Kalimantan". Figure 1, partly adapted from MacKinnon, shows the processes of degradation and regeneration. Three lines represent the different processes: the central line shows the degradation of primary forest to *I. cylindrica* grasslands; the left and right lines show the processes of reforestation in opposite directions. Natural reforestation or succession is described along the right line and accelerated reforestation or ecology-based reforestation along the left line. Figure 1 serves as a guide to the arguments presented in this chapter, which serve as a rationale for this study.

Forest disturbance practices like selective logging, clear-cutting, shifting cultivation and frequent burning create *I. cylindrica* grassland. These disturbance practices are categorised in the middle column of Figure 1. When this disturbance happens regularly on large scale the process of natural regeneration or natural succession is very difficult to establish, especially in very large connected grasslands. The process of succession depends on the size of the grasslands and the presence of pioneer species (seed sources). Limited and localised land clearance may have little impact on native plants and animals, and forest regenerates more quickly in the small clearings. These small land clearances resulting from traditional shifting agriculture may lead to a change in the species composition of residual forests, favouring trees adapted to fire, cutting and other disturbances associated with shifting cultivation (MacKie *et al*., 1987).

The final stage of large-scale degeneration is *I. cylindrica* grassland. *I. cylindrica*, called "alang alang " in Indonesia, reproduces itself prolifically, both vegetatively and by seed. It has the ability to thrive on infertile soil. Its rhizomes are extremely resistant to fire; in fact, fire kills the competitive plants and thus favours the expansion of *I. cylindrica* (Brook, 1989). Because of its high growth rate and enormous biomass production, *I. cylindrica* is a strong competitor with other plants for water, light and nutrients. The allopathic effects, combined with its great ability to compete , enable *I. cylindrica* to grow in monocultures (Sambas *et al*., 1991) and hamper natural succession.

I. cylindrica is difficult to control. Intensive mechanical site preparation is the most effective cultivation method in grassland reforestation, but is not commonly practised. The main method of control currently practised by farmers and small reforestation projects is to slash (and burn) the *I. cylindrica*. Grass pressing (i.e. lodging, rolling) is a method not used in Kalimantan for controlling I. *cylindrica*. Agricultural estates (and sometimes forestry estates) mostly practise chemical control. Farmers are also using more and more herbicides in Kalimantan. *I. cylindrica* is a light-demanding, shade-intolerant species. Biological control by suppressing the grass through shading by natural succession and by planting trees is the most obvious solution for the future.

Reforestation

Transformation of these grasslands into forest, here referred to as reforestation, is possible by natural succession or by human interference, or by a combination of both. In general, reforestation of older extended areas of I. *cylindrica* grassland is extremely difficult, because of compact and nutrient-deficient soils, hydrological instability, wide temperature variations in of the soil-rooting zone, grass competition and allelopathy and high fire susceptibility. Moreover, natural regeneration processes are hindered by annual fires and the absence of seed banks (pioneer and climax tree seed sources) and of fungal root symbionts (mycorrhizae).

The right-hand column in Figure 1 shows the sequence of the natural regeneration process if the grassland is protected against frequent fires. The progress of natural regeneration in general is slow and greatly depends, apart from fire, on the age, extent and occurrence of remnants of natural forests in the surrounding areas.

Plantation Forestry

The best known strategy for converting unproductive grassland into a more productive land use is the establishment of industrial forest plantations composed of exotic tree species. These large-scale reforestation activities have been undertaken with varying results and the sustainability of these plantations is questionable. Good soil preparation before planting is essential for the destruction of the rhizomes of *Imperata* grasses and for the establishment of plantations. Large financial investments are required for the establishment of large-scale industrial forest plantations or large-scale agricultural estates. Other transformation strategies include agroforestry and small-scale permanent agriculture.

Problems in reforestation have been studied intensively in a trial area in South Kalimantan (Otsano et al., 1997) for mainly exotic tree species. Recommended species for first rotation reforestation of grasslands must be able to colonise the site with vigorous early growth and a high survival rate. The results of experiments in South Kalimantan (Otsano *et al*., 1997) demonstrated that the fast-growing exotics are more effective in this, because - according the author - the local species are not adapted to the harsh climatic conditions and degraded soil generally characteristic of *I. cylindrica* grasslands. However, this conclusion is based on only a limited number of local species.The same author therefore recommended intensifying a species selection programme.

Accelerated regeneration, an ecology-based strategy

In the last decade, a new strategy has been under development as a reaction to the negative environmental qualities and economic feasibility of the large-scale industrial monocultures**.** This new ecology-based strategy accelerates regeneration as compared with natural regeneration or succession in grasslands, is sustainable and offers an alternative to the exotic tree species plantations. The strategy can be used in agroforestry systems, in the establishment of buffer zones around protected forests and in the reforestation of all kinds of critical land. According to Drilling (1989) and Kartawinata (1994), this strategy is known as Assisted (or Accelerated) Natural Regeneration (ANR), and has been researched in the Philippines. The strategy is a potentially rapid, efficient and cost-effective means of reforesting critical watersheds, grasslands etc. ANR is defined by Drilling as “any reforestation method that relies on natural regeneration and has weed-suppressing activities”. The approach is site specific, but there are several common steps in identifying requirements at each site, in particular, in *Imperata* grasslands rehabilitation programmes:

1. Clarification of the objectives
2. Site selection
3. Protection of the area against fire
4. Identification of existing woody plants
5. Inhibition of the grass layer (intervention)
6. Facilitation of the growth of existing woody plants
7. Continued treatment of the grass layer (maintenance, out-shading grass by trees)

8. Enrichment planting of desired species
9. Silvicultural treatments of these species

The objective of this study is to find ways of accelerating the process of grassland regeneration into an ecology-based pioneer – dipterocarp-dominated - forest system. The way to reach this target is illustrated in the left-hand column of Figure 1. The first practical step is the selection of the most adapted pioneer species to out-compete the grass (species site matching). At the same time, selection of the dipterocarp species is started. The next step is the establishment of a pioneer plantation, which is followed some years later by inter-planting with dipterocarps. After one to two decades, the pioneer-dominated dipterocarp plantation is expected to change into a Dipterocarp-dominated plantation. This plantation progressively comes to resemble a natural primary forest through natural regeneration, changing tree species composition and increasing biodiversity. Sustainable management practice is an important tool for reaching this stage. During the successive steps, silvicultural treatments are improved and tested to increase productivity and/or natural regeneration. The present study concentrates on the first step of this stage: Species elimination phase – species testing phase – species proving phase – establishment of pioneer plantation.

Burley and Wood (1976) defined the "Species elimination phase" as a mass screening of a large number of possible species in small plots during a short period. The "Species testing phase" compares a reduced number of promising species in large plots for longer periods, while the "Species proving phase" confirms the superiority of the selected species under normal planting conditions.

Pioneer species selection

Technical questions arising in the reforestation of grassland are related to species choice, to the physical difficulties in planting, competition of the grass with the newly planted trees, susceptibility to fire, soil degradation (physical as well as mineral) and soil compaction. A good choice of site-specific adapted species is of crucial importance for the ecology-based strategy, for planting as well as for natural regeneration. . Many local pioneer species thrive in harsh site conditions and are fast growing, making them useful for suppressing light-loving grasses and for reforestation schemes of plantations. However, there is little written information about most of these species.

The pioneer species to be selected should meet several criteria, the most important of which are a high survival rate, fast growth, a wide crown and early closure of the canopy. The role of pioneer species in successful *I. cylindrica* grasslands reforestation is that these species should serve as a nurse crop to shade out grasses, reduce vine infestations and provide shade over future crop trees that otherwise suffer if exposed to prolonged daily sunlight (Putz, 1993). The trees should be high light intensity-tolerant and easy to reproduce (by seed, cuttings etc.). The trees should also tolerate pests, diseases, fire, and low soil pH, water stress and low nutrient levels (N,P) to a certain degree. The most difficult standard criterion is that the species must be able to cope with the abundant *Imperata* rhizomes, not only in terms of allelopathy and mechanics, but also in terms of competition for water and nutrients. Finally, the species should be locally accepted and have a potential for various end users (Evans, 1984; Hadi, 1990; Soerianegara, 1980). A further step forward in selection is the domestication of a promising species.

Domestication

Leakey *et al*. (1997) defined domestication of a species in genetic terms as an accelerated and human-induced evolution. However, domestication is not only selection, as domestication integrates the four key processes of identification, production, management and adoption of the species. In the context of reforestation of grasslands, domestication of desired species has to be considered as a tool used by farmers, timber estates and projects to accelerate the reconversion of grasslands into productive areas. Discussion on the role of domestication cannot be separated from that of commercialisation. Intensive domestication for self-use or for an expanding or new market is based only on high incentives. *Peronema canescens* seems to provide these incentives and is therefore the first species to be domesticated. *P. canescens* has been found to have local and international commercial potential, it tolerates the competition of grasses, is fire tolerant and has a relatively fast youth growth. The results of the identification, selection and production of *P. canescens* as presented here is the first step in the domestication of this species.

Aim of this study

In summary, the aim of this study is to test the early growth potential of mainly unknown local species and a selection of known exotic species, and to monitor their suitability as species for further experiments, pilot plantations, buffer zones and agro-forests. The main emphasis is in finding species that are able to occupy the site and suppress the *Imperata* grass with minimum maintenance. The next chapter gives an account of the species selection experiment, the effects of fertiliser on growth performance and the domestication of promising species.

RESEARCH IMPLEMENTATION 1996 – 1999

Species Selection

Pioneer Species Selection

The two elimination experiments for the selection of 31 local species and 9 exotic species were laid out in a Randomised Incomplete Block Design each with four replications. The experimental sites were established in *I. cylindica* grassland in the rainy season in March 1996. Terrain preparation of all the experiments in the grassland involved only line slashing, which was conducted a week before planting, using a mattock to clear an area 150 cm wide. Small pits (approximately 25 cm deep) had been prepared before planting. The number of plants per species varied from 12 - 48.

The measurements taken 12 months after establishment were:

- survival rate
- height (cm) and diameter (mm) at ground level of each tree and
- health condition of each tree.

After analysing the data using a two-way ANOVA procedure the species were classified according their efficiency to compete with grasses, into four classes: promising, possible, less successful and not recommended species.

In Table 2, the species are ranked according their ability to compete with *I. cylindrica* after one year. This resulted in the classification of 3 promising species, 10 possible species, 16 less successful species and 11 not recommended species. *Peronema canescens* and *Calophyllum inophyllum* were the two most promising species in their competition with grasses in the first year. The relatively fast growth of *P. canescens* with a compact crown at the juvenile stage makes this species suitable for intensive shading, which is essential for the effectiveness of using forest plantations in suppressing *I. cylindrica*. The exotic species, such as *Acacia mangium*, *Eucalyptus deglupta* and *Gliricidia sepium* demonstrated a faster growth than the local species, but had a lower survival rate than the two most promising species.

Table 2 Tree species ranking, one year after establishment

Promising	**Possible**	**Not successful**	**Not recommended**
Survival : > 90 %	**75 – 89 %**	**50 – 74 %**	**< 50 %**
Height : > 115 cm	**95 – 114 cm**	**75 – 94 cm**	**< 75 cm**
Peronema canescens,	*Anthocephalus chinensis,*	*Arthocarpus sp.,*	*Aleuretas moluccana,*
Calophyllum inophyllum	*Arthocarpus elastica,*	*Alstonia scholaris,*	*Buchanania sessifolia,*
	Macaranga depressa,	*Calophyllum sp.,*	*Kokoona sp.,*
Gliricidia sepium	*Elmerillia tsiampacca,*	*Diospyros sp.,*	*Macaranga conifera,*
	Teijsmanniodedron sp.	*Duabanga moluccana,*	*Macaranga trichocarpa,*
	Acacia mangium,	*Eusideroxylon zwageri,*	*Monocarpia*
	Eucalyptus deglupta,	*Litsea garciae,*	*kalimantanensis,*
	Fleminga macrophylla,	*Macaranga gigantea,*	*Neonauclea gigantea,*
	Cajanus cajan	*Macaranga hypoleuca,*	*Schima wallichii,*
	Samanea saman.	*Macaranga lowii,*	*Vernonia arborea*
		Neolisea sp.,	*Tristaniopsis sp.*
		Parkia javanica,	
		Scarphium macropodum,	*Gmelina arborea*
		Elmerillia ovalis,	
		Leuceana diversifolia	
		Leuceana leucocophala.	

The fires in Kalimantan in 1997-1998 destroyed this experiment and only a few species survived or resprouted, namely, *P. canescens* (99%), *Gmelina arborea* (55%) and *Samanea saman* (45%)

Dipterocarp species selection

Two experiments with dipterocarp species were established in 1995: one under a canopy of residual forest and one on open *I. cylindrica* grassland. Eleven dipterocarp species were planted - mostly originating from wildings harvested near the Wanariset Research Station and raised in the Wanariset nursery. These 11 Dipterocarps with the serial numbers 1-11 were: *Shorea balangeran* (1), *S. leprosula* (2), *S. selanica* (3), *S. pauciflora* (4), *S. johorensis* (5), *S. seminis* (6), *S. ovalis* (7), *Drybalanops lanceolata* (8), *S. smithiana* (9), *S. parvifolia* (10), *S. laevis* (11). The residual *Macaranga* forest was treated to create a 60% canopy cover. A minimum site preparation was executed by slashing the shrubs and small trees in a 2-metre wide strip. The seedlings were planted at a spacing of 3 x 5 metres. The same method was applied in the open *I. cylindrica* grassland area. The layout of the experiment was a Randomised Complete Block Design with 16 trees per plot, replicated 4 times in the residual forest and 5 times in the open area.

The measurements taken 1, 12 and 25 months after planting covered:

- survival rate
- height (cm) and diameter (mm) at ground level of each tree and
- health condition of each tree.

The results of the two dipterocarp species trials demonstrated that there are differences in tolerance to multiple environmental stress (solar radiation, high temperature, competition and soil infertility) between the 11 two-year old dipterocarp species tested. Only ***Shorea balangeran*** seems to be more stress-tolerant than the 10 other species in *I. Cylindrica*-dominated grassland. This was clearly demonstrated some months after the last measurements during the dry season, just before the fire destroyed the experimental plots. The 10 other species showed higher survival rate in residual forest, as compared with the same species planted in grassland (Fig. 3) after 24 months. Three species, *S. balangeran, S leprosula* and *S. selanica*, grew faster in the grassland, compared with these species planted in residual forest (Fig. 2).

Figure 2.

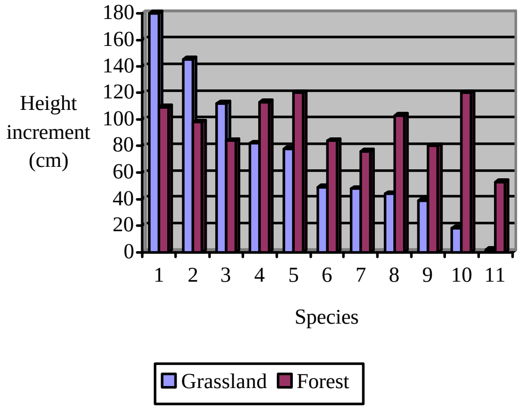
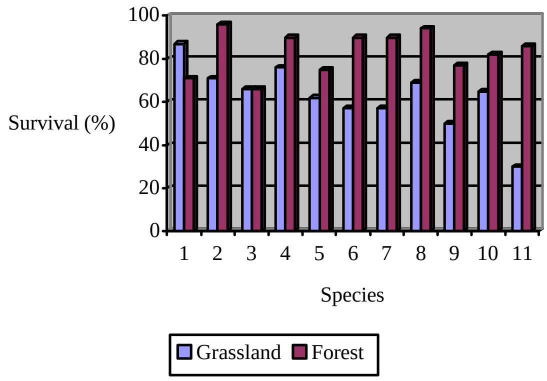


Figure 3



Figures 2 and 3 The height increment and survival (%) of 11 dipterocarp species after 24 months, planted in residual forest compared with these species planted in grassland. Numbering of species as indicated above.

Use of fertilisers

Complementary to the elimination trial, the effect of the initial application of NPK and five slow release fertilisers on the growth performance of four pioneer species were studied and measured 1, 5 and 12 months after establishment. The four species, *Acacia mangium, Anthocephalus chinensi, Macaranga pearsonii* and *Peronema canescens* were planted in 4 different experiments (Randomised Complete Block Design) all with the same fertiliser treatments. For comparison purposes, the fertiliser treatments were grouped randomly together in 6 blocks within one species.. The standard or control treatment did not receive fertilisers. The plots per treatment consisted of 4 trees with a planting distance of 1 x 2 m. A total number of 240 plants per species was tested (4 plants x 10 treatments x 6 blocks). The measurements taken 1, 5 and 12 after the establishment of the experiment were:

- survival rate
- height (cm) and diameter (mm) of each tree at 5 cm above ground level
- projection of the crown diameter of each tree after 12 months;
- the health condition of each tree using such descriptive parameters as yellow leaves, insect attack, broken branches and/or broken top
- cover of the *I. cylindrica*, which was estimated in the percentage classes 0-20, 21-40, 41-

60, 61-80 and 81-100. This variable was measured only once in the first week of March 1996, one month after the establishment of the experiment;

- in August 1997 the fertiliser experiment was destroyed by fire. The survival rate of all species was recorded 3 and 10 months after this incident. In addition, the shoot length and diameter at ground level of *P. canescens* trees were measured.

Tree growth per species (height, diameter at ground level and h/d) were analysed using the two-way ANOVA procedure for fertiliser treatments, blocks and the covariant *I. cylindrica* cover. SPSS Statistical data analysis was used for the evaluation.

The species *P. canescens* showed a very good and uniform performance and application of fertiliser did not influence its growth. However, the use of fertilisers had a positive effect on the early growth of *A.mangium*, *A. chinensis* and *M. pearsonii*. The species *A. mangium* seems to require a much higher dose of nitrogen as compared with *P. canescens*, *A. chinensis* and *M. pearsonii*. A preliminary conclusion is that the optimal dose of 4-5 grams of slow release fertiliser (Osmocote 17+9+8+4) in the planting hole is necessary for *A. chinensis* and *M. pearsonii.* The species *A. chinensis* seems to be more susceptible to draught and competition and probably requires more nutrients than *P. canescens* and *M. pearsonii.*

The 1.5 year-old plants of *P. canescens* burnt in August 1997, but resprouted vigorously after burning (99%), as opposed to *A. mangium, A. chinensis* and *M. pearsonii,* which also burnt but did not sprouted again.

Domestication of *Peronema canescens* Jack. (Verbenaceae)

In 1998, the Wanariset Research Station included the domestication of *P. canescens* in its research programme. This was based on the performance of this species achievedafter the first evaluations of the pioneer species elimination experiment and the fertiliser experiment, but especially that achieved after the fierce fires of 1997-1998. Unfortunately, these fires destroyed these experiments but, as a blessing in disguise, the fires demonstrated that *P. canescens* is a fire-tolerant species with the capacity to sprout vigorously after burning.

Westphal *et al*. (1989) and Kessler *et al*. (1994) describe the general characteristics of the family Verbenaceae and in particularly *Peronema canescens* Jack. This species is a pioneer species occurring in Peninsular Malaysia, Sumatra and Borneo. It is cultivated in Indonesia, Malaysia and Thailand. The wood of *Peronema* (with the local name of sungkai) is mostly used locally for roof trusses, bridge construction and furniture. The attractive, beautiful linear figures in the wood make sungkai suitable for fancy veneer, cabinets, carvings etc. and the wood is exported to Japan. For that reason, natural populations of mature old trees are becoming extinct in Kalimantan. *Peronema* occurs in residual forest on dry and slightly moist soil at an altitude of up to 600 m. Luxuriant natural regeneration may occur in open places, such as bushlands, *I. cylindrica* grasslands, fallow or logged-over forest. Dominant natural populations of this species were present on infertile black soil hills in the ITCI concession (a large timber concession near Balikpapan) area in 1998. This indicates that the species may have the capacity to rehabilitate critical land such as grasslands and mining sites. Plants propagated spontaneously from root and branch cuttings were observed in natural populations. It was interesting to note that pigs are propagators of *Peronema* through breaking branches for nest building.

Artificial regeneration is carried out by planting branch cuttings, 2.5 cm in diameter and 25 cm long at angle directly in the field on 1 to 2 m wide strips. More common is the planting of branch cuttings directly in polybags in the nursery, transplanting them about 4 to 6 months later. Spacing in the field is commonly 3 x 2 m or 4 x 2 m. Several experiments have been conducted since 1998 and have already led to numerous useful conclusions. A short description of the experiments is given in the following paragraphs.

Collecting cuttings of 12 origins (provenances) (Tolkamp, 1998)

In June and October 1998 two field trips for the collection of cuttings and seeds from natural *P. canescens* populations were organised in South and East Kalimantan, respectively. More than 100.000 cuttings of 12 origins (provenances) were collected and propagated in the nursery. The cuttings collected along the road to Banjirmasim in South Kalimantan came from heavily burnt forest and consisted of semi-hardwood cuttings of low quality from sprouted stumps. No seed-bearing trees were observed during that period. The second survey was organised in the unburnt logged-over forest of the ITCI concession near the Meratus mountain in East Kalimantan. The rooted cuttings were planted in 1998 and 1999 in the reforestation area of *I. cylindrica* grassland.

The effect of storage duration on the rooting ability of P. canescens cuttings (Riskan & Rayan, unpublished)

Lignified *P. canescens*' branches of 1.5 cm length and with a diameter of 1.5 – 2 cm were collected. Bunches of branches for the production of 600 cuttings were stored in the shade of trees near the nursery (the minimum humidity was 60 % during daylight). 25 cuttings in 4 replicates were produced successively in polybags every ten days over a 50 day period. The rooting ability was evaluated 30 days after propagation.

The conclusions from this experiment are:

- the rooting ability of the cuttings, propagated 1, 10, 20, 30, 40 or 50 days after collection, was 94%, 91%, 94%, 98%, 98% and 97%, respectively (average = 95%).
- lignified branches of *P. canescens* can be stored for 50 days or more under tree shade before losing their rooting ability.

The effect of the origin of cuttings on the rooting ability of P. canescens (Tolkamp & Alkadafi, unpublished).

In June 1998 cuttings collected from resprouted stumps and originating from three sites in South Kalimantan were propagated in polybags and in the open soil. The survival rate and shoot length of 850 cuttings were recorded 30, 58 and 91 days after planting..

The conclusions of this experiment are:

- the optimal production period for *P. canescens* cuttings in the nursery is 4 months;
- lignified (hardwood) cuttings from branches are superior in rooting percentage and growth to partly lignified (semi-hardwood) cuttings originateing from stumps (rooting percentage respectively 76-100% and 12-36%);
- the rate of success is the same for propagation in polybags and propagation in the open soil.
- the production costs of propagated cuttings in the open soil are much lower than those of cuttings produced in polybags. However, introduction of the cutting production method in the open soil depends on the success of the establishment of bare root cuttings in the *I. cylindrica* grasslands

Direct planting of unrooted and rooted P. canescens cuttings in I. Cylindrica-dominated grasslands (Tolkamp & Taupik, unpublished)

Cuttings were planted on 11 November 1998 in small pits at a spacing of 2 x 1 metres. Manual weeding was carried out in the form of strip clearance by slashing the grass every 3 months. No fertilisers were applied before or after planting. Five treatments were tested in a randomised complete block design: (1) unrooted 100 cm cuttings; (2) unrooted 50 cm cuttings; (3) unrooted 25 cm cuttings; (4) bare root cuttings and (5) cuttings produced in polybags

The results after 4 months showed that:

- direct planting of unrooted cuttings with a length of 50 cm had the highest survival rate of 93%, but the survival rate was not significantly different from that of cuttings with a length a 100 cm (76%), cuttings of 25 cm (82%) and cuttings propagated in polybags (82%).
- bare root cuttings demonstrated a very low survival rate of 20% and this survival rate was significantly different (P = 0.00) from that of the other cutting methods.
- planting of bare root cuttings in grassland is not recommended, because of dehydration and root damage problems during transport and planting. This also means that the production programme of *P. canescens* cuttings in the open soil has been cancelled.
- establishment of *P. canescens* plantations with unrooted, lignified (hardwood) branch cuttings of 50 cm length is technically feasible and economically attractive in *I. cylindrica* grasslands. Observations on the growth are continuing.

Other related activities for the domestication of P. canescens

- Two types of *P. canescens* hedge orchards, namely a clonal and a ‘true to origin’ hedge orchard, were established in 1998 and in the last months of 1999. The objectives are to assure a constant supply of high quality plant material of known origin in the future for potential users (farmers, reforestation projects etc).

- *P. canescens* is a promising species suitable for a fire break in that it possesses the required properties (ITTO, 1997). A proposal was written to study the growth performance of 45 *P. canescens* clones in relation to the species’ efficiency as a fuel break. The objective of this study is to select the most suitable clone as a fuel break tree and to compare the results of the same clones, planted in a plantation and in the seed orchard. Plant material is ready in the nursery.

- Depletion of mature, natural populations through over-exploitation and fires caused seed shortages of *P. canescens*. Although artificial propagation by seed is not commonly practised and knowledge of the seed technology of this species is not available at the Wanariset, it was proposed to establish a seed orchard of the valid clones in the near future.

- An experiment on the effect of shading of *Shorea leprosula* by *P. canescens* with the aim of contributing to greater knowledge of the water stress physiology of this dipterocarp species is included in an ongoing PhD study (Priadjati).

- An agroforest plantation consisting of *Peronema canescens* (sungkai) next to *Parkia javanica* (petai) progenies, *Nephelium cuspidatum* var. *robustum* (rambutan) and *Arthocarpus integer* (cempedak) was established on *I. cylindrica* grassland in November 1998.

DISCUSSION AND CONCLUSIONS

The Tropenbos-Kalimantan Project presents an ecology-based strategy, which accelerates regeneration, is sustainable and offers a better alternative to exotic tree plantations. The strategy relies on the potentials of natural regeneration (which differs on each site site) and accelerates regeneration through planting a mix of adapted local pioneer species in an initial phase of reforestation (see Figure 1). In a later phase, climax species (Dipterocarps) are planted in between the pioneer species to approach a natural regeneration process, developing towards a more sustainable dipterocarp-dominated plantation. The strategy is already proving to be a potentially rapid, efficient and cost-effective way of establishing buffer zones around protected forests and of reforestating all kinds of critical land. The results from experiences with species selection, fertiliser application and with the domestication of desired species are promising, but the results are based on a short period and the time is not yet ripe for final recommendations.

Species selection

Increasing the diversity of species for use in grassland reforestation schemes can reduce the risk of failures, both biological and economical. Long-term functional forest use planning (single functions or multiple functions, e.g. conservation, timber, hydrology, NTF-production, agroforestry, recreation) and species site matching should produce the most suitable species. Indigenous species not yet tested may complement or outperform the limited number of exotic species currently used in grassland reforestation activities.

A limited number of local species have so far been tested in Kalimantan and the results are not yet encouraging. However, the introduction of indigenous species to exotic tree plantations should be considered as a technical transition phase and is certainly not a desirable option. Better alternatives are the systems based on natural regeneration or enrichment planting or a combination of these two reforestation methods in different variations. These alternatives may turn out to be a way of overcoming both short-term and long-term problems. This paper has affirmed that a limited number of local species can be successfully used in the establishment of a nursing pioneer plantation. Species selection at the second phase of integrating local climax tree species into the pioneer plantation and at the third phase of natural regeneration in mixed forest will certainly have its problems. However, the prospects of finding suitable indigenous species for this ecology-based strategy for the reforestation of *I. cylindrica* grasslands are very promising. The species elimination experiments of the Wanariset Station added further information to that from the South Kalimantan experiments and confirmed the need for more local species research.

The results of the species elimination experiment, based on the performance of 40 species under extreme grassland conditions, are still preliminary, but confirm that there is considerable potential for some native species under extreme conditions. Two species, *Peronema canescens* and *Calophyllum inophyllum*, were selected for further experiments in pilot plantations, fuel breaks and agroforests. *Acacia. mangium* outgrew local species, confirming the results in South Kalimantan (Otsano *et al*., 1997). However, Otsano also pointed to the fact that *P. canescens* and *C. inophyllum* were promising among the local species. This also supports the recommendation to plant at least 2500 trees of these species per hectare, based on growth, shade providing capacity and early canopy closure properties.

Application of fertiliser

For most species fertiliser application is essential as a silvicultural treatment to establish pioneer plantations for successful competition and suppression of *I. cylindrica* grass. The use of slow release fertilisers showed that the method can be recommended to stimulate early growth of the desired trees. The use of fertilisers was species' specific and had a positive effect on the early growth of *Acacia mangium*, and also on recommended indigenous species. The species *Peronema canescens* showed a very good and uniform performance in *I. cylindrica* grassland areas with low soil nutrient levels. More research is needed to clarify these aspects.

Domestication

Peronema canescens is the most appropriate species for the reforestation of grasslands. The species is easy to propagate by means of branch cuttings. Direct planting in the field of cuttings of 50 cm length is very successful. Direct planting of unrooted branch cuttings reduces the planting costs and makes reforestation of these grasslands more attractive. Another advantage is that the lignified cuttings can be stored for about 50 days without loosing their rooting ability. This makes the transport of cuttings over long distances feasible and the large-scale propagation of *P. canescens* attractive. The species has the capacity to compete with *I. cylindrica* grass and suppression of the grass can be made more effective through planting at close intervals. The species is fire-tolerant and is locally used a as commercial tree for its timber. All these characteristics merit more research in further domestication of this very useful species.

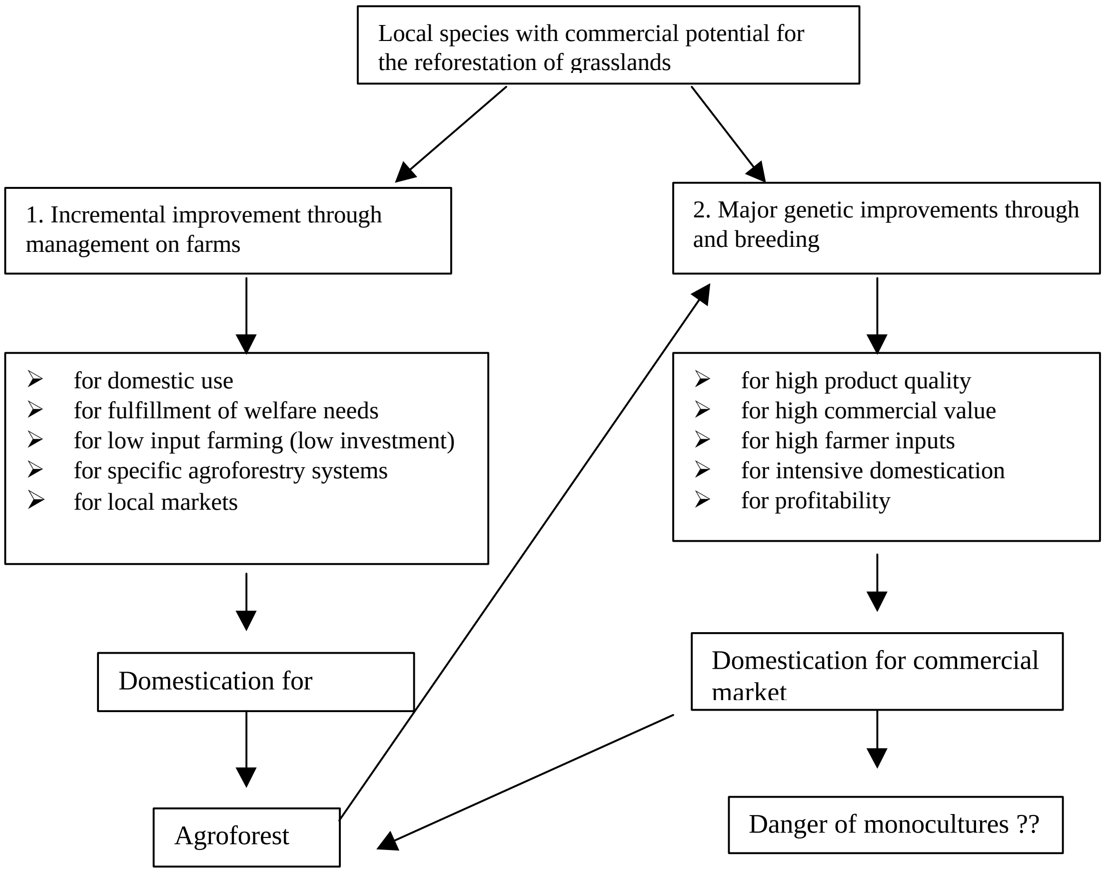


Figure 4 Two strategies in the domestication and commercialisation of a species and its products (modified from Leakey *et al*., 1997)

Two strategies for the domestication of selected species will be followed in further Wanariset research:

- incremental improvement through management on farm; and
- major leaps in tree improvement by genetic selection and breeding.

Figure 4, modified from Leakey et al., 1997, represents these two strategies diagrammatically. The first strategy is farmer-oriented, while the second is market-oriented. The two strategies are not mutually exclusive; collected *P. canescens* cuttings of different origins and many mother trees are used in both strategies. The selected cultivars or clones from genetic improvement programmes can be grown on farms as well as on large plantations (Figure 4). Monocultures are not established. The project will inform concessionaires, reforestation projects and farmers of the great economic and environmental potential of mixtures of pioneer and climax species for converting grasslands. For that reason, feasibility studies directed at solving individual problems and integrated research in an extended programme are recommended. It should be a common effort of all the stakeholders, i.e. of concessionaires, reforestation projects, farmers and researchers. It is also suggested that this research should be integrated into national regional and international research programmes, such as the programmes of Tropenbos International, CIFOR, ICRAF, BIO-REFOR.

RECOMMENDATIONS

The significance of the study is the introduction of an ecology-based strategy – which is a site specific, accelerated natural regeneration method - as a practical tool for the rehabilitation of degraded areas, in particular, the reforestation of *Imperata cylindrica* grasslands in Indonesia. The Wanariset Research Station, located in a mosaic like landscape, is pre-eminently suitable for conducting research in conservation, tropical forest ecology, species-site matching, and reforestation of *I. cylindrica* grasslands, agroforestry and social forestry.

In this context, it is recommended that:

- implementation be started of the ecology-based strategy for the rehabilitation of critical land with farmers in the Wanariset area.
- research on this ecology based strategy in the Wanariset Research Forest should continue and be intensified
- native tree resources for appropriate grassland reforestation should be explored and studied
- The domestication of tree species for on-farm-use and for the commercial market should continue and be intensified. The domestication of *Peronema canescens and Calophyllum inophyllum*, in particular, should proceed.
- A feasibility study be implemented to investigate the possibilities of direct sowing to reforest grasslands in combination with different silvicultural treatments. Controlled fires for land preparation should form part of this study.
- Plantations consisting of mixtures of *Peronema canescens*, dipterocarps and fruit trees should be created to serve as buffers for existing primary forests, plantations, estate crops, agricultural fields and villages, thus reducing the risk of encroachment and the penetration of fires and grasses.
- The direct sowing of a mixture of selected species (such as *Trema* sp.). be tested at places where seed (from the seed bank) is exhausted. Sowing should take place after controlled burning at the beginning of the rainy season.
- establish close collaboration between Indonesian, Asian and international organisations.

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NON-TIMBER FOREST PRODUCTS IN A CHANGING ENVIRONMENT

Johan L.C.H. van Valkenburg

1. INTRODUCTION

Non-timber forest products (NTFPs) are currently receiving wide attention throughout the tropics. It is increasingly acknowledged that the exploitation of NTFPs can play an important role in the conservation and development of tropical rainforest areas. Sustainable exploitation of NTFPs is thought to be a possible alternative to the non-sustainable forest management currently practised in most tropical countries. These products provide food and materials for domestic use, while some of them also provide cash income when traded on local, national or international markets.

The ecological and economic aspects of NTFP exploitation, however, not to mention its social implications, are not well known. A good introduction to the manifold implications of NTFP extraction and study methods can be found in some recent Tropenbos publications (Ros-Tonen *et al.*, 1995; 1998). The present paper focuses on the ecological and economic potential of NTFPs in East Kalimantan.

The research on which this paper is based was undertaken from 1991-1995 as part of the International MOF-Tropenbos Kalimantan Project based at the Wanariset Research station in Samboja, East Kalimantan. This project aims to develop appropriate techniques and guidelines for sustainable forest management. It is being implemented by the Indonesian Agency for Forestry Research and Development of the Ministry of Forestry and Estate Crops, the Institute for Forestry and Nature Research IBN-DLO, and the National Herbarium in the Netherlands, together with the Indonesian state forestry enterprises P.T. INHUTANI I and P.T. INHUTANI II.

The aims of the NTFP study can be summarised as follows:
- to provide an inventory of commercially important NTFPs in selected parts of East Kalimantan and to evaluate their economic potential;
- to compare the distribution and abundance of NTFP in various areas in East Kalimantan;
- to study the effects of logging on species composition and NTFP abundance;
- to contribute basic data needed for establishing guidelines for the sustainable management of NTFP resources.

In order to study the effects of extraction and disturbance on NTFP resources, areas were selected with a traditional land use and unaffected by commercial extraction, as well as some areas showing various levels of disturbance and affected by commercial extraction (see Figure 1).

Remnant forest in the Wanariset area surrounding the research station was studied in detail for soil conditions and tree species composition. A supplementary inventory of rattan was conducted for this study.

Figure 1 Map of the study area

The P.T. International Timber Corporation Indonesia (ITCI) concession northwest of Balikpapan was selected for a comparison of primary and logged-over forest areas. Research on soil conditions and the species composition of trees in permanent plots had already been conducted within the framework of the International MOF-Tropenbos Kalimantan project (Van Bremen et al., 1990 and van Eijk-Bos, unpublished).

The village of Long Sungai Barang in the Apo Kayan ‘provided’ undisturbed forest in an area with a traditional land use unaffected by market demands. The site was formerly the location of a Man and Biosphere project and the social aspects and ecology of shifting cultivation had already received special attention. For detailed information on the methods used, see van Valkenburg (1997).

2. THE PROBLEM IN A BROAD PERSPECTIVE

The forests of East Kalimantan harbour a great diversity of plant species. The composition of their tree species, in general, and of rattan and other NTFP species, in particular, is heterogeneous. Species abundance also varies greatly. This heterogeneity is the cause of regionally differing possibilities for development.

The immense species richness of tropical rainforests may contain a wealth of potentially economically important plants, yet at the same time limits the potential of extraction, because of the generally low density of individual species (e.g. Plotkin and Famolare, 1992; La Frankie, 1994). The economic potential of oligarchic forests, which contain fewer species, may therefore in general be higher (Peters and Hammond, 1990; Nepstad and Schwarzman, 1992). For this reason, virtually all plantation systems, in both temperate and tropical regions, focus on a very limited number of species.

In spite of ecological constraints, NTFP extraction from natural forests was claimed to be the economically most competitive land use for Peru by Peters *et al.* (1989). In Ecuador, too, the net present value (NPV) was found to be much higher for NTFP extraction (US $ 1,257-2,539) than for timber extraction (US $ 180) or agriculture (US $ 500), with a net annual value of US $ 63-136/ha. (Grimes *et al.,* 1994). However, the formulae used are often difficult to compare. Under present-day economic conditions, however, the assumption that NTFP extraction leads to forest conservation is difficult to validate (Fearnside, 1989; Lawrence *et al.*, 1995; Siebert, 1991).

Management of the forest may result in considerably higher yields. Management can be limited to selectively promoting favoured useful plants within the primary forest (Anderson, 1990) or planting rattan in logged-over forest (personal observation). A more intensive management system is enrichment planting in fallow vegetation, creating rattan, rubber or fruit gardens. What all these management systems have in common is that they preserve the biotic and physical aspects of the forest environment, with a high species diversity and with trees as a major structural component (e.g. Alcorn, 1984; Padoch and Peters, 1993; Sardjono, 1990; Torquebiau, 1984). The integration of cash crops into the swidden cycle or as a simultaneous activity of shifting cultivators, with the enriched fallow being maintained as such, has been reported for Kalimantan, Sulawesi and Sumatra from as early as the beginning of the 19th century (Donner, 1987; Dove, 1993; Weinstock, 1983).

NTFP extraction from natural forest is an economically feasible land-use option only if the real environmental costs of development, such as soil erosion and loss of watershed protection are included (Nepstad and Schwarzman, 1992). Economic valuation is often obscured by direct or indirect subsidies and import taxes, as for the timber industry in Indonesia (Nepstad and Schwarzman, 1992) and for rubber prices in Brazil (Fearnside, 1989). The same political instruments of subsidies and import/export taxes may well be used to create strategic reserves of natural forests.

Social and economic aspects also determine the feasibility of NTFP development. Fluctuating prices influence the management of NTFP resources and have social implications. Rising prices of rattan, for instance, resulted in an influx of ‘outsiders’ demanding access to the rattan gardens in the middle Mahakam area (Weinstock, 1983). The high prices of gaharu (*Aquilaria* spp.) resulted in an influx of ‘outsiders’ in the Apo Kayan, thereby jeopardising the resource and depriving local inhabitants of future harvests (van Valkenburg, 1997).

The extraction of NTFP is rarely a full-time occupation. It is only part of a multiple economic strategy of people in rural areas. It provides for both subsistence needs and cash income (e.g. Browder, 1992; Denevan and Padoch, 1987; Pierce-Colfer *et al.*, 1992). People respond to changing needs and possibilities and base their choices on past experiences, choosing what they consider the most profitable option (Vayda *et al.*, 1980; Kartawinata and Vayda, 1984; Pierce-Colfer and Soedjito, 1988). When prices for rubber decrease, a Brazilian rubber tapper family's cultivated land area will increase (Browder, 1992). By contrast, a boom in rubber prices in West Kalimantan does not necessarily result in a change of labour allocation from rice cultivation to rubber tapping, as rice cultivation remains the main priority (Dove, 1993). However, a harvest failure or increased consumption needs may result in increased rubber tapping. In Pasir, East Kalimantan, the time devoted to rice cultivation, rattan gardens and coffee, was influenced by the remaining stock of rice and the prices for rattan and coffee (Mayer, 1989). Moreover, as the people’s economic prosperity rises, the importance of NTFP extraction in providing a cash income in general decreases (Siebert and Belsky, 1983; Godoy and Bawa, 1993). Using NTFP extraction as an instrument for improving the economic prosperity of rural people may thus lead to a fall in NTFP extraction in the long term.

The above aspects demonstrate that any development of NTFP extraction needs to be evaluated in environmental, as well as in social and economic terms. The choice for a given land use will depend on the local situation.

3. RESULTS

3.1 Present land use in East Kalimantan: some examples

The economic value of NTFP extraction has to be compared with other land-use systems in order to judge its economic potential. Land-use systems that mimic the structure and species diversity of natural forest are judged to be most favourable. In the present study only land-use systems with a low external input and with trees as a major structural component have been included.

Various methods have been used to calculate the net present value (NPV) of a given land use and all have their limitations. The calculation of the NPV of NTFP extraction with multiple harvests at irregular intervals, in particular, poses problems. A formula based on a summation of annual returns and costs has to be used.[1] In this formula, R is the gross revenue, C stands for the total costs, t is the time in years, and r is the real discount rate, a factor influenced by the interest rate (see e.g. Filius, 1992). Another formula used in some of the often cited articles on the valuation of tropical rainforest is NPV = Net Value/($1-e^{-rt}$), where Net Value stands for gross revenue minus total costs, r is the real discount rate and t is the length of rotation in years (e.g. Peters *et al.,* 1989; Grimes *et al.*, 1994). This method can be used for land-use systems with a single harvest at the end of the rotation and the formula equals NPV = NAV/r for land-use systems with constant annual returns. However, the rotation cycle of the various land-use systems differs. In order to compare these systems, the NPV is multiplied by a Capital Recovery Factor that is related to the length of the rotation cycle (Gittinger, 1973). This results in a Net Annual Income value.

[1] $$NPV = \sum_{t=o}^{end} (R - C)_t \left(\frac{1}{1+r}\right)^t$$ (R: revenue; C: costs; r: real discount rate; t: year of rotation)

The direct costs and benefits of the harvesting can be quantified, but the environmental costs of a particular land use are more difficult to quantify. What are the costs of a loss in water retention capacity, soil erosion, decline in downstream fish populations and a loss in subsistence products formerly collected from natural forests? These long-term environmental costs are probably much higher than the present-day financial gain. The logging practices in East Kalimantan changed the forest structure over large areas and made the forests more susceptible to fire (Schindele, 1989). The devastating fires in 1982/1983 seriously affected people's livelihoods, their impact on the environment was immense, and the total costs to the national economy amounted to US $ 9.075 billion (Schindele, 1989). Serious fires again raged through extensive areas of East Kalimantan in 1991 and 1994, the same areas that had also been affected by the 1982/1983 fires. Finally, the 1997/1998 fires raged through large tracts of forest in East Kalimantan and various other provinces of Indonesia. The direct costs and loss of revenue for the Indonesian economy have been estimated at US $ 5-6 billion (Sunderlin, 1998).

Table 1 Comparison of the economic aspects of various land-use systems in Kalimantan with trees as a major structural component (values in US$; Env. costs = environmental costs, i.e. loss of watershed protection, erosion; increasing from + to +++) (for further details, see van Valkenburg, 1997).

	Rotation (years)	**NPV * (r=10%)**	**@NPV (r=10%)**	**Net annual income/ha (r=10%)#**	**Env. costs**
Timber 1st harvest		4,250	160	(50)	+++
Timber 2nd harvest	35	2,116	80	(25)	+++
Multiple extraction forestry		460	42	(46)	+
Rattan plantation periodically flooded		500		224	++
Rattan plantation Barong Tongkok	30		65-140	(7-15)	+
Traditional home garden		500-1,500	45-135	(50-149)	+
Illipe plantation	60		480	(48)	+
Improved home garden	60				+
After 20 years			241-1,081	(28-127)	
After 60 years			778-1,473	(78-148)	

* For annual yielding systems: Net Present Value = Net Annual Value / r (r : real discount rate).
* For non-annual yielding systems: Net Present Value = Net Annual Value / $1\text{-}r^{-rt}$ (r : real discount rate, t : rotation time in years).
@NPV: for timber, revenue and costs [forced to last year of rotation].
In parentheses: Net Annual Income = @NPV * CRF (Capital Recovery Factor)

$$@NPV = \sum_{t=o}^{end} (R - C)_t \left(\frac{1}{1+r}\right)^t$$ (R: revenue; C: costs; r: real discount rate; t: year of rotation)

The economic aspects of present land-use systems with low external input and trees as a major structural component are summarised in Table 1. As in Sarawak and South America, besides ecological constraints, the possibilities and costs of transport are key factors in determining the economic feasibility of a land-use system (Burgers, 1991; Nepstad and Schwarzman, 1992; Denevan and Padoch, 1987). Because of the perishable nature of the products, mixed fruit gardens will be confined to areas at close proximity to the market, whereas rattan gardens, although less profitable per unit of land, will be a viable option for more remote areas. Subsidies or favourable loans, however, are a decisive economic factor in the establishment of rubber gardens and pulpwood plantations (e.g. *Paraserianthes falcataria*).

3.2 Management options in East Kalimantan

The land-use systems found in East Kalimantan, combined with the economic, ecological and social constraints, were factors in the appraisal of the potential of various NTFPs (Table 2). This potential can be translated into various land-use options, which are presented in order of gradually increasing management input and reduced species diversity. The environmental costs are most favourable for managed nature reserves. As these are very difficult to quantify, they are not included in Table 2. A common feature of all land-use types is that trees are the major component of the system.

Table 2 Potential for development of various non-timber forest products in East Kalimantan (++ = very good; + = good; - = poor)

	Rattan	**Fresh fruits**	**Illipe**	**Exudates** (excl. *Hevea)*
World market	++	-	++	-
Local market	+	++	-	+/-
Storage	++	-	+	+
Regular (annual) supply	++	+/-	-	++
Large plantations	++	-	++	-
Smallholder management	++	++	++	+/-
Labour allocation	++	+	+	++
Incorporation in swidden cycle	++	+	-	-
Human / livestock consumption	-	++	++	-

Source: van Valkenburg, 1997

3.2.1 Nature reserves

The establishment and preservation of nature reserves in the strict sense (IUCN *et al.*, 1991), excluding any human interference, will affect a very limited geographical area. For historical, social and practical reasons, the participation of the local people in park management is to be preferred. The traditional collection of forest produce often has a long history and has, in general, not severely threatened the forest. Acknowledgement of the controlled traditional harvesting rights of local people will strengthen or maintain their commitment to preserving the resource for future use. If local people do not feel responsible for the forest, protected areas will have little future.

As nature reserves cannot be considered in isolation from local subsistence agricultural practices, these should be included in an overall conservation and development plan. Leases or stewardship arrangements between rural communities and the government could serve as a tool. Local communities must clearly receive direct or indirect financial compensation for preserving forest areas that might otherwise be converted into a land use that is financially more profitable in the short-term. Intensification of the present land use may well be a means of reducing the pressure on the remaining forest land (Lawrence *et al.*, 1995; Browder, 1992). Involvement of the local community and strict enforcement of stewardship regulations is essential to prevent further encroachment on the remaining forest. Besides traditional harvesting rights and security of tenure, reciprocal benefits for indigenous people should also be considered.

The NTFPs of highest economic importance in East Kalimantan are rattan, fresh fruits and exudates. If these were to be included in a combined extraction model for nature reserves, the Net Annual Income in primary forest in the Apo Kayan would amount to US$ 46/ha (van Valkenburg, 1997). The economic feasibility of rattan collection depends on transport costs. Harvesting rattan is ecologically sustainable as long as the vitality of clumps is not damaged and the resource is given sufficient time to recover (van Valkenburg, 1997). Fresh fruit harvesting is an economically realistic option only for areas with markets at close proximity.

This combined extraction can be considered equivalent to the High Diversity Forestry proposed by La Frankie (1994). This multiple-product extraction scheme very much resembles the traditional hunter-gatherer system with minimal manipulation of the forest. By combining harvests, the search time for each product can be reduced, thereby avoiding the economic drawback of high diversity and low density of individual species. Whereas La Frankie assumes the simultaneous extraction of various products in order to reduce the high costs of searching per tree, a combination of fruit and rattan collection is most unlikely. The projected return depends on the species composition of the forest and distance to nearby markets, and will therefore vary considerably between areas.

3.2.2 Integration of NTFP production in commercial forest estates

As producing timber is the primary goal of a commercial timber estate, NTFP production should not interfere with timber production. NTFP production might be achieved by using multi-purpose tree species or by combining timber and NTFP-yielding species.

Using multi-purpose tree species for enrichment planting in the present TPI[2] rotation of 35 years is probably most profitable if *Shorea* species yielding illipe fat are used (van Valkenburg, 1997). The trees produce a good quality timber and there is a well-established market for illipe fat. Either the concession holder or a subcontractor could harvest the nuts. A complicating factor is that a concession holder is not officially allowed to fell *Shorea* trees yielding illipe nuts, so he will be disinclined to plant these species if he cannot obtain a permit to fell the trees.

Combining the production of timber and resin or latex is complicated for two reasons. Tapping of resin and latex competes with tree growth, as it competes for nutrients and may lead to disfigured trunks (Torqeubiau, 1984). Secondly, extraction would require permanent access by the tapper, thereby causing permanent disturbance and problems with enforcing trespassing regulations.

Combining timber with fruit production would limit the choice of fruit species, as it precludes small and medium-sized species. It also faces problems with both the harvesting and marketing of generally perishable fruits. Control of trespassing is difficult. Enrichment planting with trees specifically for fruit production gives a wide variety of species that can be used, but problems with harvesting, marketing and control of trespassing remain.

Mixing timber and large diameter rattan in a 35-year rotation has several management advantages. Extraction of rattan should take place prior to timber harvesting and the same infrastructure could be used. Harvesting is conducted in strictly defined periods, facilitating control. The quality of the canes should be good, considering the length of rotation and the abundance of support trees. Each cane can be expected to yield eight three-metre lengths, representing a value of Rp. 4000 (or US $ 2). The large diameter canes are used in furniture making and constitute the basis of the Indonesian rattan industry.

3.2.3 Integration of NTFP production in village or community forestry

At present, logged-over forest areas with no commercial prospects for the concession holder are designated as conversion forest, either as pulpwood plantations or transmigration projects. These areas could be leased or handed over to local communities on condition that the forest cover is maintained. This would open up prospects for enrichment planting with rattan, fruit trees, illipe species or other useful trees. This may well be designated as secondary high diversity forestry, the environmental advantages of which are obvious.

[2] TPI (Tebang Pilih Indonesia) is selective felling according to Indonesian regulations, based on a 35-year rotation scheme.

Boosting rattan production is good for the national economy, especially for employment. The production of small diameter rattan is to be preferred, in view of the shorter time span between planting and the first harvest (7-10 years). Success is dependent both on enforcement of the regulations and the creation of markets for the produce. Management and the sale of produce from these communal forests could be organised through the already widely established co-operative system in Indonesia.

Land-use systems incorporating NTFP are already well established in Kalimantan. As stated above, mixed fruit and illipe/tengkawang gardens have a long history in East and West Kalimantan, while rattan gardens are well-developed in areas of South and East Kalimantan. However, there are possibilities for improvement of these existing systems, as will be discussed below.

3.2.4 Optimising NTFP production in a new agroforestry system

An agroforestry system could be created with a canopy of large fruit trees (100 ha^{-1}) and a second layer of medium-sized, shade tolerant fruit trees (100 ha^{-1}). The core of 200 trees per hectare leaves ample space for additional plants.

For the canopy, a selection can be made of illipe species (e.g. *Shorea macrophylla*, *S. pinanga*) *Artocarpus integer*, *Durio zibethinus*, various *Mangifera* species and *Parkia speciosa*. Suitable shade-tolerant fruit trees include *Baccaurea* spp., *Dimocarpus longan*, *Durio kutejensis*, *Lansium domesticum* and *Nephelium lappaceum.* The balance of species will vary according to market possibilities and ecological and social constraints. The shade-tolerant fruit trees start producing after five years. After ten years the ‘canopy’ trees will have overtopped the small fruit trees, and cempedak (*Artocarpus integer*) and durian (*Durio zibethinus*) trees will start producing. Finally, the first illipe harvest can be expected after twenty years.

At present price levels and a real discount rate of 10 %, the Net Annual Income from just 200 core trees could range from US $ 28-127 after twenty years to US $ 78-148 after sixty years(Table 1). After sixty years a decision can be made on whether to fell the canopy trees gradually for timber or to maintain the trees for fruit production.

The problem with this proposed man-made forest is, of course, whether people are willing to invest in such a long rotation system. The system reaches its highest production at a time when the person who planted the trees has probably died.

3.2.5 Pitfalls

Promoting the extraction of a NTFP may result in over-harvesting and a drop in prices. This poses a threat to ecological and economic sustainability and also has adverse effects for the collectors. Diversification to reduce the dependency on a limited number of NTFPs is the solution (Nepstad and Schwarzman, 1992). This applies both to the dependency on rubber and Brazil nut in South America (e.g. Daly, 1990; Kainer and Duryea, 1992), and rattan in Southeast Asia (e.g. Godoy and Tan, 1991). The proposed improved mixed fruit home garden (see above) is an example of such a product diversification strategy.

A further emphasis on species with a good current commercial value may pose a threat to other indigenous fruit species or varieties that will no longer be planted or replaced. The wealth of genetic diversity of indigenous fruit trees that has so far been preserved in traditional Dayak home gardens (Bompard and Kostermans, 1992; Padoch and Peters, 1993; Seibert, 1989) is at stake. This will limit the future potential for crop resistance breeding, an acknowledged problem for cultivated plants and livestock worldwide.

All the possibilities for, and constraints on, the development of NTFPs described in the previous paragraphs depend on one simple issue of paramount importance: who owns the land or its produce? Without vested tenure rights, nothing can be developed. This is a vital issue in the development of sustainable NTFP extraction worldwide.

Traditionally, the ownership of plants in Dayak societies does not necessarily coincide with ownership of the land (Chin, 1985; Weinstock and Vergara, 1987). This clearly contrasts with the western concept of land tenure, under which the ownership of plants cannot be alienated from land tenure rights. The present Indonesian legal system therefore gives rise to conflicts in Borneo. Furthermore, the forest management systems as practised by Dayak people are often deemed to be non-existent, since no agricultural crop has been planted.

Formerly, the harvesting of NTFPs such as rattan, gaharu and damar was regulated by the village community (Chin, 1985; Jessup and Peluso, 1986; Weinstock and Vergara, 1987). Now, however, the granting of harvesting rights has more or less become a function of the state, which complicates matters even more. Coordination between the various departments which grant permits is often lacking and enforcement of the regulations is difficult, because of understaffing (Nepstad and Schwarzman, 1992; Pierce-Colfer *et al.*, 1992). The lack of law enforcement and the power vacuum experienced after the fall of Suharto in 1998 have made illegal logging and encroachment on protected areas more likely (Anderson and Daju Pradnja Resosudarmo, 1999).

The combination of timber and NTFP production in timber estates is complicated by the different harvesting regulations, as has been explained in the preceding paragraphs.

4. SOME IMPLICATIONS OF THE FINANCIAL CRISIS AND THE IMF AGREEMENT

The management options and the financial picture presented above are based on the situation up to 1997, but the 1997 and 1998 forest fires and the financial crisis that hit Indonesia in 1998 have greatly altered the picture. The IMF agreement that was negotiated has had a considerable impact on forest policy and regulations.

The export ban on rattan imposed in 1988 will be replaced by an export tax reduction on raw and semi-processed rattan from 30% *ad valorem* to 20% by December 1998, 15% by December 1999 and 10% by December 2000. At the same time, an inter-island tax equivalent to this will be introduced to prevent smuggling from the country. This will most likely induce a rise in prices for collectors and promote quality control. One problem, however, is that large areas of forest in the Mahakam catchment area and its tributaries – the traditional sources of the bulk of rattan from East Kalimantan - have been severely damaged by the recent forest fires and this will most likely result in a severe reduction of the standing stock. This again will give rise to higher prices and over-exploitation of the resource, a problem common to ‘free-for-all’ resources that gain temporary economic importance.

The export ban on logs has been replaced by an export tax regime similar to that on rattan. Whether this will encourage sustainable management is doubtful. Another policy change imposed through the IMF loan agreement is the reduction of land conversion targets to environmentally sustainable levels and the implementation of a system of performance bonds for forest concessions. This implicitly contains the admission that present-day practice is non-sustainable. At the same time, restrictions on foreign investment in palm-oil plantations have been removed and the government has replaced the export ban on palm oil with an export tax with effect from April 1998 (at 40% from January 1999) to guarantee adequate domestic supply. This may well stimulate the conversion of permanent forest land to oil palm plantations, which is an effect obviously contradictory to the aim of reducing land-conversion rates to sustainable levels.

In Pasir and Kutai in East Kalimantan, people's response to the combined effect of the economic crisis and the 1997-1998 forest fires once again exemplified the flexibility of traditional livelihood strategies. As returns from rice planting dropped, people in remote areas shifted their attention to illegal logging and rattan harvesting in order to generate cash income (Anderson and Daju Pradnja Resosudarmo, 1999).

5. CONCLUSION AND PERSPECTIVES FOR FUTURE RESEARCH

The present-day management of permanent production forest areas of East Kalimantan is far from sustainable. This applies equally to its ecological and its economic and social aspects. The widespread 1997-98 forest fires once again exemplify this, whatever the actual cause of the fires in particular localities.

If short-term economic gain at the local level is a guideline for land-use planning, then the extraction of NTFPs from primary forest areas (at a net annual income of up to US$ 46/ha) in East Kalimantan is not economically the most competitive land use (see Table 1). If, however, watershed protection, erosion control, biodiversity conservation and other environmental services are given a financial value, it becomes an economically viable option from a national and regional perspective, although not for individual landowners or users. Leaving forest areas intact for the future may well prove to be more profitable in the long run, as pristine areas will become increasingly scarce. The value of technically irreplaceable assets will be appreciated or felt only when they are no longer there.

As forest concessions have already been granted and vast areas consist of logged-over forest, consideration should be given to the best possible land use for these areas. This would definitely not be a conversion to plantation forests of fast growing tree species such as *Paraserianthes falcataria*. An enormous loss of biodiversity would be the result and these plantations are virtually void of rattan, an NTFP of great importance for employment in Indonesia. Furthermore, the sustainability of this land use is doubtful, in view of the removal of large amounts of nutrients after each rotation and the susceptibility of monocultures to pests. Present-day mechanical logging is too destructive, but can be improved ecologically without negative economic effects (e.g. Hendrison, 1990). These logged-over areas can be preserved as permanent production forest and used to boost the production of large-diameter rattan and illipe (*Shorea* spp.). The high labour input required for harvesting and processing is especially important for employment in rural areas. Apart from these commercial forest estates, the potential for enrichment planting in disturbed habitats involving local populations appears promising. The traditional agroforestry systems could well be improved, or even expanded, by including depleted permanent production forest.

Sound management of the Indonesian permanent forest land plays a pivotal role in poverty alleviation, even in the midst of the present crisis. Forest land is a key source of income for millions of people in remote areas, generating employment for millions of Indonesians working in the forest-related sector. Forest-derived foreign income ranks third behind oil/natural gas and textiles.

Future research should be geared towards integrated forest management, including both timber and non-timber resources. For optimum management, more knowledge is needed of the ecological requirements of the species involved. On the basis of the species' ecological requirements, economic and social considerations will further shape the management regime. This may well differ considerably between large commercial timber estates and forest areas under participatory forestry. Some form of state control and a more refined forestry law are essential for the viability of such a system.

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DIVERSITY IN WOODY PIONEER SPECIES AFTER THE 1997/98 FIRES IN KALIMANTAN

Karel A.O. Eichhorn

GUILDS OF PLANTS IN THE TROPICAL RAIN FORESTS

The tropical rain forests (TRF) in the world are generally very similar in their structure and ecological processes, in spite of their often pronounced differences in composition of species and higher taxa (Whitmore, 1984; Mabberley, 1992). This is well illustrated by the regeneration in gaps in the forest canopy created by falling mature trees. Generally, these gaps are first colonised by herbaceous and woody plants which share a whole set of ecological characteristics, including fast growth, intolerance of shade, short life span, high palatability, and small persistent seeds which germinate only at high light intensities (Ewel, 1980; Whitmore, 1984). These plants are usually referred to as pioneers. After the pioneers have colonised a gap, they are gradually replaced by species which share the opposite set of characteristics.

Swaine and Whitmore (1988) reviewed the different classifications of plants according to their role in the regeneration of TRF gaps and concluded that only a few of them are properly explained, and that the terminology used is generally confused by a lack of precise definitions. They themselves recognise only two main groups of tree species observable in TRF: pioneer and climax or non-pioneer species. They define pioneer species as “species whose seeds can only germinate in gaps in the forest canopy open to the sky and in which full sunlight impinges at the ground level for at least part of the day”. They further state: “All pioneers also require full sunlight for seedling establishment and growth. As a consequence, seedlings and young plants are found in openings in the forest (tree-fall gaps, roadsides, landslides, felled areas etc.) and are never found under a closed forest canopy, including their own. Non-pioneer or climax species are able to germinate, establish and survive in forest shade. Young plants of these species are thus commonly found below a canopy, but may also be seen in open environments”.

Although pioneer species share a set of ecological characteristics, they can be very different in others. Tropical ecologists have mainly focussed so far on the characteristics in which pioneer species differ from climax species (Davies, 1998). It is only recently that more attention has been paid to the often considerable differences within these groups. Pioneer species include plants of different growth forms, longevity and height at maturity, different crown characters, breeding systems, and photosynthetic rates. In spite of their definition, they even show considerable differences in their requirements for germination, since light intensity, red far-red ratio and temperature can be all triggers for it, either separately or in combination (Vasquez-Yanes and Orozco-Segovia, 1993). Furthermore, closely related pioneer species can be also very different in their ecological characteristics, as has recently been illustrated by different species of the genus of *Macaranga* (Davies, 1998; Davies *et al*., 1998). As a consequence of their different morphological and physiological characteristics, pioneer species can differ considerably in their preferences for gap size (Brokaw, 1987) and in their ability to colonise secondary habitats, as has been illustrated by the many species elimination trials for reforestation of *Imperata* grasslands in Kalimantan. These differences between pioneer species have led some authors to conclude that the dichotomy in pioneers and climax species represents only the two extremes of a continuum (e.g., Alvarez-Buylla and Martinez-Ramos, 1992).

Swaine and Whitmore (1988) state that, in contrast to the dichotomy between pioneers and climax species, all the variation within both two groups is continuous. They believe that the recognition of subgroups is acceptable, as long as it is realised that they are arbitrary segments of a continuum.

SPECIES OF TROPICAL SECONDARY VEGETATIONS

Before human interference, disturbance in TRF was mainly the result of falling mature trees and was consequently small in scale. Large-scale disturbances could be caused by landslides, earthquakes, hurricanes, animals (elephants, caterpillars), fire and drought (Mabberley, 1992). After the introduction of shifting cultivation, disturbance of TRF continued to be relatively small-scale and in equilibrium with the recovery of the forest (Whitmore, 1984). In modern times, however, human interference has assumed the form of the destruction of huge areas of TRF by logging, fire and mining activities. As a result, these areas have been converted into tropical secondary forests (TSF) dominated by woody pioneers, where climax species are scarce or even completely absent, especially when no remnant trees of the original forest have survived.

Although the conversion of TRF into TSF changes most environmental factors in the same direction as the formation of tree-fall gaps in TRF, these shifts can expected to be much more pronounced in TSF: no published direct comparative studies are known, but light intensity, soil and air temperature and drought stress are strongly correlated with gap size (Denslow, 1987; Bazzaz and Picket, 1980). Moreover, the forest floor is often severely damaged in TSF (Whitmore, 1984; Cannon *et al*., 1998), leading to a loss of nutrients due to erosion. Because pioneer species show considerable differences in their preferred gap size (Denslow, 1980; Brokaw 1985, 1987), only a subset of all pioneers are expected to be fully adapted to habitats resulting from large-scale disturbance. Only these pioneer species should therefore be referred to as secondary species, or species of secondary vegetations, terms often confused with pioneer species. Other pioneer species are less adapted to the circumstances in secondary vegetations and are easily squeezed out by the real secondary species.

THE 1997/98 FIRES IN EAST KALIMANTAN

Induced by the El Niño Southern Oscillation (ENSO) climatic phenomenon, millions of hectares of land were ravaged by the extensive fires of 1997 and 1998 in Southeast Asia, including both forest and non-forest areas. The fires and accompanying smoke caused serious air pollution, damage to the public health, loss of life, destruction of property and substantial economic losses in many parts of Southeast Asia.

The most severely damaged area is East Kalimantan: after moderate damage by the fires in 1997, huge areas were burnt between January and May 1998 (Dennis, 1998). The hotspots were largely concentrated in the central part of the Indonesian province, in the environs of Balikpapan and Samarinda. The burnt areas included grassland, brush land, degenerated forests, secondary forest, and *Macaranga* stands, with surface fires burning in primary forest. The official estimate of burnt land stands at about 0.5 million hectares, but recent calculations of International Forest Fire Management Project (IFFM) in Samarinda indicate that the real losses are at least 5 million ha. (pers. comm. A.A. Hoffmann, 1999).

Like everywhere in Southeast Asia, small-scale fires are a normal phenomenon in Kalimantan, as both smallholders and owners of larger areas of land use it to clear land for cultivation. However, large-scale logging activities, even when based on sustainable management, make the forests very susceptible to drought and fire (Dennis, 1998; Goldammer, 1999). In the exceptionally dry years induced by ENSO, fires spread easily into the forests and damaged huge areas of it. During the last two decades, millions of hectares of forest have been burnt in this way, especially in 1982/83 and 1997/98, with minor events in 1987, 1991 and 1994.

Once a forest has been burnt, it has a much higher risk of being burnt again (Dennis, 1998; Goldammer, 1999). The repeated disturbances by logging and fire convert TRF into secondary forests, shrub-dominated stands, fern-dominated stands and, finally, into alang-alang dominated grasslands, with the prospects for recovery of the original forest becoming lower after each new disturbance event (Uhl *et al*., 1988). Two years after the fires in East Kalimantan, woody pioneer species dominate the burnt areas, together with many herbaceous species and small lianas. Examples of currently dominant pioneer species belong to the genera of *Macaranga*, *Homalanthus, Trema, Piper, Melastoma* and *Chromalaena*.

SCALE DEPENDENT DIVERSITY EFFECTS OF DISTURBANCE ON PIONEER SPECIES

Field observations indicate that not all pioneer species profit from large-scale disturbances like the fires of 1997/98 in Kalimantan. Only a subset of all pioneer species seems to be fully adapted to the man-made environments. Other pioneer species seem to be easily forced out by them. Successful secondary species also invade new regions where they did not occur before, thereby out-competing local pioneer species. Consequently, pioneer species diversity may be even lower in TSF than in TRF, and large-scale disturbances may therefore lead to a considerable loss of diversity in pioneer species, in spite of the fact that pioneer species increase considerably in terms of biomass.

Ecologists are generally not aware of the loss of pioneer species diversity after large-scale disturbance of TRF, because it is obscured by the experimental design of most ecological studies. Ecological studies of tropical succession are usually carried out in a relatively small number of plots within relatively small study sites (Brown and Lugo, 1990). At the small-scale level of a few plots or transects, the number of pioneer species is usually much higher in TSF. This is a result of the strong increase in density of individuals in a limited number of pioneer species. When large areas of TSF are compared with large areas of TRF, the total number of pioneer species might be larger in TRF, because more pioneer species occur here (in low densities).

This scale-dependent loss of diversity in pioneer species can be analysed by means of randomised species accumulation curves (Figure 2). Randomised species accumulation curves of pioneer species in TSF are expected to increase strongly at low values for the area axis, quickly reaching their relatively low maximum value for the species axis. The curves for TRF are expected to increase more slowly and finally reach a higher maximum value.

HYPOTHESIS

After large-scale disturbance of TRF by fire, the diversity in pioneer species is increased when assessed in small areas, but decreased when assessed in larger areas.

So far, only the actual species diversity of TRF and TSF has been discussed. Many TRF sites are known to have many pioneer species present only as dormant seeds in the soil (Saulei and Swaine, 1988; Garwood, 1989; Metcalfe and Turner, 1998), and absent in the standing crop itself. Since TSF are mainly composed of species recently established after large-scale disturbance, the species composition of the standing crop is very similar to the seed bank (Uhl *et al*., 1981, Saulei and Swaine, 1988). The addition of species present only as seeds in the soil to the overall species richness increases the pioneer diversity of TRF much more than that of TSF. In other words, if the potential diversity is assessed instead of the actual diversity, the decrease in pioneer species diversity due to large-scale disturbance of TRF is even more pronounced.

The potential diversity of pioneer species can be expressed in randomised species accumulation curves in two different ways. The first method includes species present as germinating seeds in soil samples in the species accumulation curves, in the second method the species accumulation curve is based on gaps in primary forests only. Both methods will be applied in this study.

HYPOTHESIS

After large-scale disturbance of TRF by fire, the decrease in the diversity in pioneer species at the larger scale is even more pronounced if the potential diversity is assessed instead of the actual diversity.

Study sites

The study sites for this project are located in the Balikpapan–Samarinda region, East Kalimantan. The current stage of succession after the fires of 1997/98 provides excellent opportunities for studying the diversity effects of large-scale disturbance events on pioneer species. Two study sites of 450 ha will be located in the Sungai Wain Protected Reserve. In this reserve, burnt forest (burnt in 1998) will be compared with primary forest. A third 450 ha study site will be located in the Wanariset Research Forest, along the road from Wanariset field station towards Semoi. At this site, repeatedly burnt forest (burnt in 1982/83 and 1997/98) will be studied.

In addition to disturbance by fire, disturbance by illegal logging takes place on a small scale at all three sites (Frederikson and de Kam, 1999). Logging is known to increase the size of the seed bank in the soil (Saulei and Swaine, 1988), but fire is generally more destructive in logged-over forests compared with primary forests (Woods, 1989, Goldammer, 1999). Logging in advance of fire may therefore have ambivalent effects on the pioneer stand after fire. Since disturbance by fire is expected to be much more intensive than disturbance by drought, logging and other human activities at the study sites, disturbance effects are expected to be mainly the result of the fires.

To ensure that differences in botanical composition are mainly the result of the fires, the three study sites will be situated in similar parts of forest in terms of their topography, soil type, pH, and drainage. The sites also must have been originally covered by Mixed Dipterocarp Forest (MDF), the most common type of rain forest in Kalimantan (MacKinnon *et al*., 1996).

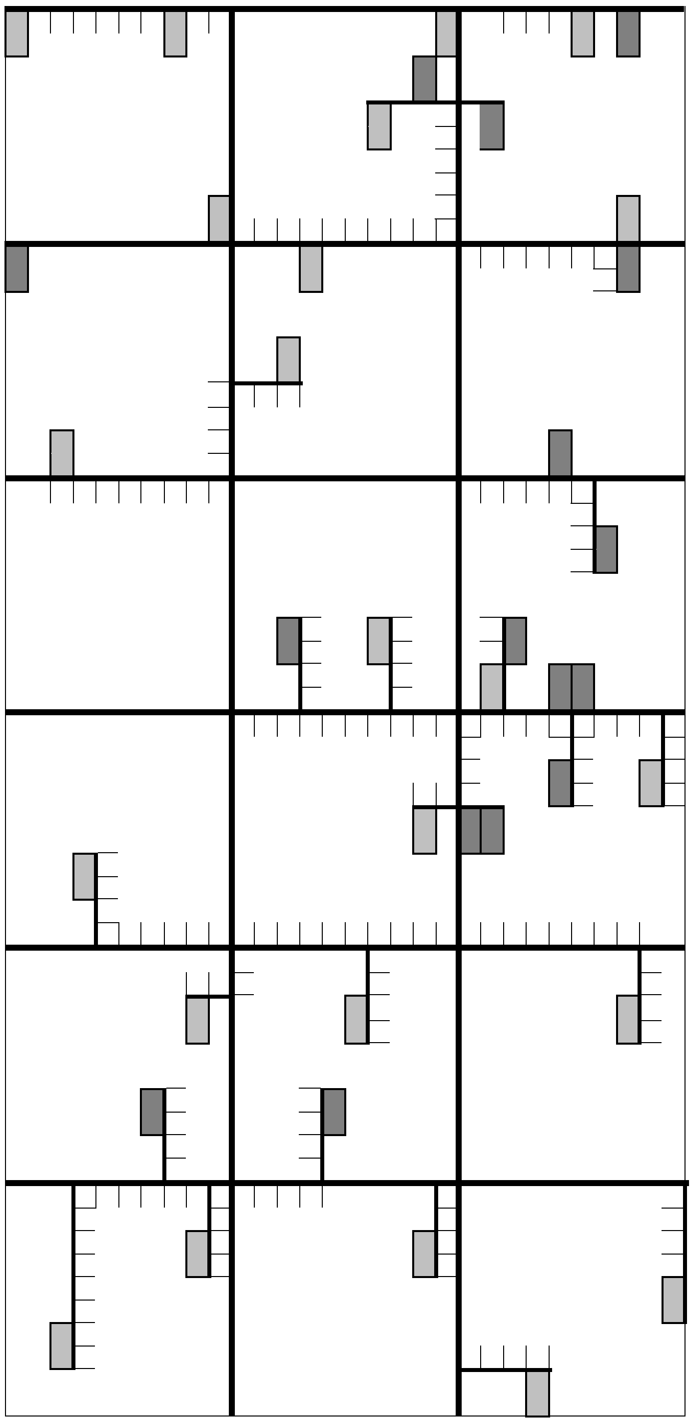

Figure 1 Example of a 18 ha (300 x 600 m) study area containing 40 random plots.

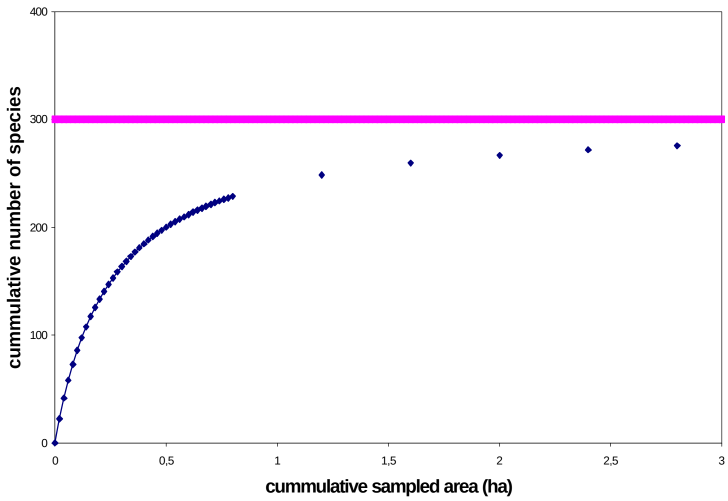

Figure 2 Example of a randomised species accumulation curve based on 40 subplots in a particular study area. The
total number of vascular plants (300 species) in this study area is estimated by mathematical extrapolation of the randomised species accumulation curve.

In the course of recording the botanical composition of a particular study area, the more plots that have already been recorded, the fewer new species per additional plot are expected to be observed (Figure 2). Ultimately, recording additional plots will not add new species to the list of the study area and the number of species recorded will be the same as the total number of species in the area. As it is impossible to survey this number of plots in the study areas, the total number of species in the area will be estimated by means of an index, which is in fact a mathematical extrapolation of the species area curve based on 40 recorded plots for the study area. This method will enable the botanical diversity between the forest types to be compared at the levels of 0.0008, 0.02, 0.72, 18, and 450 ha (Figure 3).

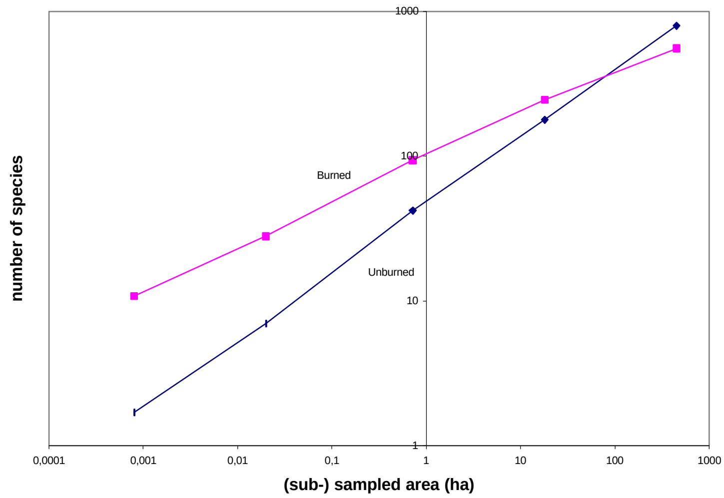

Figure 3 Hypothetical species-area curves for the diversity in pioneer species in burnt and unburnt areas. On the basis of estimates using randomised species accumulation curves, the diversity is assessed in areas of 0.0008, 0.02, 0.72, 18, and 450 ha. According to the first hypothesis, burnt TSF is expected to be more

diverse when assessed on a small scale, while (unburnt) TRF is more diverse when assessed on a larger scale. Note that both axes are on a log-scale.

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TREE DIVERSITY IN SECONDARY FORESTS OF KALIMANTAN, INDONESIA

Paul J.A. Keßler

Biodiversity is the total variety of life on our earth. The term encompasses genes, species, ecosystems and their relative abundance. I will restrict myself to plant species diversity in the terrestrial tropical evergreen forests ecosystem of Kalimantan, Indonesia. Knowledge of this variety is still limited, as only about 1.4 million of an estimated 5 to 30 million species of animals, plants, fungi and microbes have been described so far (Wilson, 1988). Kalimantan is one of the centres of tree diversity in South East Asia and it is estimated that between 3000 to 4000 tree species occur in Borneo (Soepadmo, 1995; Argent and Saridan, 1998) for which we do not have a comprehensive flora of any kind nor even a concise up-to-date checklist. Recent floristic accounts for Kalimantan by Keßler and Sidiyasa (1994), Newman *et al*. (1996; 1998), and Argent and Saridan (1998) cover probably only 1000 tree species, as there is considerable overlap. Trees in our context are not defined according to the size category usually accepted within the forestry sector (i.e. more than 5 m tall or exceeding 10 cm diameter; or for commercial timber over 20 m tall or exceeding 35 cm in diameter) but as all woody plants with the main upright stems over 2 m tall and 3 cm in diameter. The reason for departing from the current use is that the woody mature plants in secondary forest are considerably smaller in comparison with primary forest. Our current research concentrates on the inventory of secondary forests mainly in South and East Kalimantan, where we collected more than 2500 plant specimens from this habitat. The information from these collections is stored in the BRAHMS (Botanical Research and Herbarium Management Systems) database (© Denis Filer, Oxford) and will provide a crucial knowledge base to underpin the future conservation and management of Kalimantan's extraordinary biodiversity.

Tree diversity is a good indicator for the integration of forests and is therefore often used in the forestry sector during pre and post harvesting surveys or for environmental impact studies to define different forest types. A major division has been made between primary (mature, virgin) and secondary forests. Unfortunately, both terms are highly ambiguous and therefore need to be defined in our context.

Primary forests are the natural vegetation of any area and are dictated by a combination of biotic and abiotic factors like recent topography, altitude, geology, climate etc. as well as historical conditions of geology and climate. The influence of man is theoretically absent, although in our era man has virtually conquered all parts of the world and therefore even the remotest areas show more or less strong human influences.
The primary forest includes about 11 types in Kalimantan:

1. "Lowland Mixed Dipterocarp forest (sea level up to 300 m altitude)"
2. "Hill Dipterocarp forest (between 300 and 900 m altitude)"
3. "Bornean Ironwood Dipterocarp forest"
4. "Mangrove"
5. "Beach vegetation"
6. "Peat and freshwater swamp forest"
7. "Heath forests" (kerangas)

8. "Forest on limestone"
9. "Forest on ultrabasic/ultramafic soils"
10. "Montane forest (above 900 m altitude)"
11. "Moss forests (above 1800 m altitude)"

Certain vegetation communities, their structure and, sometimes, indicator species characterise all these forest types. An example of the latter is the occurrence and dominance of *Eusideroxylon zwageri* (Bornean Ironwood) and *Shorea laevis* (Bangkirai) in the "Bornean Ironwood Dipterocarp forest" or certain Rhizophoraceae in Mangrove formations along the coast. Certain species are confined to ultrabasic/ultramafic (*Borneodendron aenigmaticum*, Euphorbiaceae) or limestone soils (*Phaphiopedilum* spp., Orchidaceae) and may be used as representatives for the whole vegetation type.

The term secondary forest is even more difficult to interpret. In the literature there is almost no consensus other than the agreement that secondary forest is forest that results from the disturbance of other forests. Brown and Lugo (1990) define secondary forests in the broad sense as "those forests formed as a consequence of human impact on forest land", thus excluding forest resulting from natural disturbance such as land slides, natural fires, hurricanes etc. Other authors (Corlett, 1995; Richards, 1996; Whitmore, 1984) restrict secondary forest to forest which has regrowth after complete clearance. In Indonesia the term "belukar" is used as a local name for this type of (fallow) forest and secondary forest is restricted or refers only to forest after logging activities. Unfortunately, there is no clear-cut demarcation line between these land uses, as forests may be logged for a few trees per hectare only or may be severely logged or logged several times. It is often also very difficult in the field to distinguish between the different types and the history of the land use may not be evident any more. This is the reason why I refer to secondary forest as those forest types which clearly show a major disturbance of their structure or composition, whether caused by natural factors or human impact. This secondary forest is usually not older than 60 to 80 years; forests beyond this age, if adjacent to mature forests, are often indistinguishable from primary forest to the casual observer, as both the structure and the composition are no longer very different any more.

Relatively young stages (up to 20 years after complete removal of the original vegetation) are easy to recognise as belonging to the secondary forest type. The number of species is relatively low (c. 50 tree species per hectare), in contrast to primary forest, where 180 to 240 species per hectare may be observed in East Kalimantan. Sometimes even pure stands, often formed by *Macaranga hypoleuca* or *M. gigantea*, can be found and stem diameter distribution is very even. In a 15 year-old stand the diameter of almost all dominant trees is between 30 and 40 cm. Epiphytes like mosses, lichens, ferns or higher plants, which are so characteristic of the primary forest, are absent, as are stranglers, saprophytes or parasites. A 10-25 year old secondary forest has almost no ground layer, as the large leaves with a high content of tannic acid do not decompose very fast. The absence of a ground layer is also due to the relatively high temperature and low moisture of the degraded soils, on which a top humus layer can develop only very slowly. In the best case one can observe members of the Marantaceae like *Phrynium* spp. or Zingiberaceae like different *Etlingera* species. Other ground layer families like Gesneriaceae, with the genera *Didymocarpus* and *Cyrtandra*, Begoniaceae (*Begonia* spp.), various ferns or terrestrial orchids are absent or very rare.

In East Kalimantan shifting cultivation (slash and burn practices) and logging activities are the main reasons for the conversion of primary forest into secondary forest. The latter facilitates the encroachment of farmers or others, usually migrants and not indigenous people, searching for forest land to clear, as logging and skid roads link this land to populated places. The flawed application of legislation therefore leads to illegal cutting practices on a large scale. During the last twenty years the secondary forests in the world have grown vastly in extent, and Kalimantan is no exception. The logged-over forests are exceptionally sensitive to fire, especially during prolonged drought. This is mainly due to much dry debris (dead bark, stumps and branches, as well as dry leaves). The most recent forest fires devastated between 3 and 5 million hectares of forest land during 1982/1983 and probably much more than 5 million hectares during 1997 /1998 in Indonesia. In Kalimantan, the Central and Eastern provinces, in particular, were among the most severely hit areas. In Central Kalimantan, the huge peat-swamp area, of which one million hectares had been clear-cut to be converted into farm land, was almost totally burnt, as the peat formed one of the best fuels for sustaining the fire. Because of the extreme severe drought not only secondary forest was affected, but also primary forest. This meant that vast parts are no longer covered by primary or secondary forest trees, but by Alang-Alang (*Imperata cylindrica*) grass and other early pioneer species, e.g. ferns like *Dicranopteris* and *Lygodium* spp., shrubs or herbs like *Chromolaena odorata* (= *Eupatorium odoratum*, Compositae), *Lantana camara* (Verbenaceae), *Melastoma polyanthum* (Fig.1) or *M. malabathricum* (Melastomataceae), and *Paspalum conjugatum* (Poaceae), which are considered noxious weeds. Many woody climbers usually start their life in forest gaps and are therefore now abundant in this type of land. Among them, *Merremia* spp. (Convolvulaceae), *Cayratia* spp., *Cissus* sp., *Ampelocissus* spp. (Vitaceae), and *Uncaria* spp. (Rubiaceae) are the most vigorous ones and usually only *Macaranga* trees may be able, to lift these mats allowing the establishment of other tree seedlings. These lianas may totally prevent even natural rehabilitation with indigenous secondary forest trees, especially if fires regularly occur at relatively short intervals. Some plant families have been promoted by fire and there was a switch in the most prominent from Dipterocarpaceae in primary forest to the Euphorbiaceae in the burnt areas. The genera *Homalanthus*, *Macaranga* and *Mallotus* with *Macaranga gigantea* or *M. hypoleuca* and *Mallotus mollissimus* and *M. paniculatus*, in particular, are able to establish almost pure stands under certain conditions. All are very light demanding and fast growing and a diameter increment of 2 cm per year is quite common, especially in the pioneer species of the genus *Macaranga*. Species of other genera are also seize the opportunity to establish themselves in burnt forests, e.g. *Ficus* spp. (Moraceae); *Octomeles sumatrana* (Datiscaceae), *Leea* spp. (Leeaceae), *Anthocephalus chinensis* (Rubiaceae), *Trema* spp. (Ulmaceae), the neophyte *Piper aduncum* (Fig. 2, Piperaceae) or *Vitex* spp. (Verbenaceae). Some primary forest species are even fire-resistant, but natural regeneration is not favoured. The following species may be mentioned: *Eusideroxylon zwageri* (Lauraceae), a primary forest species, but able to resprout very well, *Fagraea racemosa* (Loganiaceae), or *Diospyros* spp. (Ebenaceae). Among the palms, mature trees of the genera *Borassodendron*, *Licuala*, and *Pholidocarpus* may survive, as they are relatively large, so that fire is unable to reach the growing tip.

Many primary forest plant families are suppressed by fires, the most important one being the dominant Dipterocarpaceae, which forms the skeleton of lowland rainforest. They burn readily because of their relatively thin bark, high content of flammable oleo-resins (damar) and their inability to resprout. Other families include the Anacardiaceae, Annonaceae, Burseraceae, Fagaceae, Meliaceae, Myristicaceae, Myrtaceae, Sapindaceae and Sapotaceae, of which most genera are indicators of primary forest. Regular, repeated burning as is commonly practised by

the slash and burn farmers or large-scale fires are unfortunately leading to a terminal stage in succession, i.e. the *Imperata cylindrica* (Alang-Alang) association.
Forest regeneration after clear cutting or burning via natural succession will be successful only if the gap size is not too large and the area is not too far away from mature primary forest trees serving as a source for the recalcitrant seeds of shade-tolerant species. Under natural conditions, an old, big emergent tree may fall down and create a gap of about 0.04 ha,. Bigger gaps occur in hilly country after landslides or lightning in association with convectional rain storms or cyclones. The actual composition follows a certain trend, but is virtually impossible to predict, as several factors such as the past history and treatment of a site, as well as chance have great impact of the forest development.

If big gaps are created, they are found to be colonised by a group of species, rare or absent in the undergrowth of high forest. This group is light-demanding in its early life and cannot grow up even under its own shade. These plants have been called pioneers or nomads by van Steenis (1958) and are characterised by rapid height growth in youth, rapid girth growth at least in youth, wood of low density (a feature which is correlated with it) and its usually pale colour. Dispersal is very effective, as these species flower and fruit copiously and frequently and individuals start to become fertile at an early age. Seeds are tiny and mainly wind dispersed, they have a long dormancy and germinate after the stimulation of either bright light or high temperature or both. Two groups can be distinguished within the pioneers: short-lived and long-lived. An example are the *Macaranga gigantea* stands behind the Wanariset research area, which started to die on a larger scale from 1995, about 12 years after the 1982/1983 forest fires. They had grown to about 20 m in height and reached a diameter of about 35 cm. Other species, like *Trema cannabina* (Ulmaceae) and *Homalanthus populneus* (Euphorbiaceae), are very short lived. After the very recent fires in 1997/1998, a large area in North Kutei has been covered by almost pure stands of *Homalanthus populneus*, which reached about 2 m in height six months after establishment. In contrast, long-lived species may reach 50 m in height and over 1 m in diameter. Examples from Kalimantan include *Endospermum diadenum* (Fig. 3) and *E. peltatum* (Euphorbiaceae), *Anthocephalus chinensis* (Rubiaceae) and *Octomeles sumatranus* (Datiscaceae), which may reach relatively great ages (up to 90 years). Some other species show features of pioneer habit, but lack the aggression of true ones. They are strong light demanders, but never occur in pure stands, but mainly scattered. *Dyera costulata* (Fig. 4) and several *Alstonia* spp. (Apocynaceae) exhibit this character, as well as *Schima wallichii* (Theaceae), *Dillenia indica* (Dilleniaceae) and *Vernonia arborea* (Compositae). All the latter species are of very considerable economic interest, as the demand is more for soft, pale timber as a source of cellulose or fibres and less for construction timber. Some trees of the early succession stage are also valued and of great use to villagers. Trema species are known to fix nitrogen, as do several legumes. Fast-growing *Macaranga* provide timber for temporary construction and roots and leaves are used in traditional medicine.

A pathway (after Whitten *et al*., 1987) shows the different associations derived by different management regimes possible from mature climax forest in Kalimantan.

Mature lowland Mixed Dipterocarp forests

↓

Forest clearance

↓

Paspalum conjugatum association

1. No burning or cutting (area close to primary forest) → young secondary forest

→ old secondary forest → Mature lowland mixed Dipterocarp forest

2. Regular burning → *Imperata cylindrica* association

3. Grazing and cutting → *Centhotheca lappacea*, *Eragrostis atrovirens*, *Desmodium triflorum* association

This scheme implies that regular burning, cutting/grazing form the major thread for the rehabilitation of cleared land and that burning especially has to be banned in order to establish at least young secondary forest. As most of the recent damaged land is too far away from primary forest, there is very little chance that the secondary forests will develop into primary forest even after a relatively long period . There is no possibility of a natural seed source of primary forest tree species, which means that there will be a cycle of short, middle, and long-lived secondary forest tree species.

Mature lowland Mixed Dipterocarp forest

↓

Clear cut

↓

Early pioneers

↓

Middle-lived pioneer species

↓

Eventually long-lived pioneer species

↓

Death

These cyclic changes also have important implications for the conservation of primary forests. Since we know that there will be almost no natural increment of this ecosystem, we should try to totally protect the remnants of this very unique habitat. The diversity of secondary forests should be increased, using different economically important tree species in underplanting projects. These may include trees providing high quality timber, such as many Dipterocarpaceae, Sapotaceae, Leguminosae or *Eusideroxylon zwageri*. Another option is to plant fruit-providing species like *Shorea* sect. *Pachycarpae* (Tengkawang or Illipe nuts); *Nephelium* spp. (Rambutan), *Artocarpus* spp. (Bread- and Jackfruit), *Baccaurea* spp. (Rambai) and others, as they may provide revenue at an earlier stage. This type of forest may also be a source of certain small diameter rattans and may also house different medicinal plants used in the traditional way. The latter are very promising taxa, as they are now almost unobtainable from the wild.

ACKNOWLEDGEMENTS

This study has been carried out within the framework of the International MOFEC-Tropenbos-Kalimantan Project. I would like to thank the staff of Herbarium Wanariset (WAN), who supported my studies in various ways. Without the very valuable help of the tree climbers and herbarium technicians Ambriansyah, Arifin Zainal, Arbainsyah, Adriansyah, Didi and Kustaniah, we would not have been able to establish the herbarium collection and its database, which was our main source of information. My counterpart, colleague, and friend Dr. Kade Sidiyasa (WAN) supported the work immensely and co-operated on many occasions. Mr. Priyono (WAN) made the beautiful drawings, which I appreciate very much. Last but not least, I would like to thank my colleagues at the National Herbarium of the Netherlands, Leiden University Branch, who helped me in identifying many of our collections from Kalimantan.

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Figure 1 Melastoma polyanthum (Melastomataceae)

Figure 2 Piper aduncum (Piperaceae)

Figure 3 Endospermum diadenum (Euphorbiaceae)

Figure 4 Dyera costulata (Apocynaceae)

SECONDARY FOREST SUCCESSION OF RAINFORESTS IN EAST KALIMANTAN: A PRELIMINARY DATA ANALYSIS

René Verburg, Ferry Slik, Gerrit Heil, Marco Roos and Pieter Baas

SUMMARY

Today, large areas of primary rainforest in Kalimantan have been converted into secondary forests. The state of secondary forests is not permanent, because forests may recover from disturbance through secondary succession. Vegetation structure and species composition after disturbance may differ widely among secondary forests, depending on disturbance type, the time elapsed since disturbance and local site conditions. Because of this, it becomes very difficult to predict the effects of disturbance on future changes in species composition.

During secondary succession, species composition will change in such way that, in forests disturbed recently, only the composition of small trees will deviate from that of virgin forests while, in forests disturbed longer ago, the composition of the larger trees will have changed. To test whether succession in secondary forests can be studied using such a size-structured analysis, we applied a Detrended Correspondence Analysis (DCA) to a forest inventory database. This database contained information on the diameter measurements of tree species ≥ 10 cm DBH. In forests that were burnt 1 year ago we found relatively small shifts in species composition for small trees (trees with a diameter of 10-20 cm DBH). The largest deviation in species composition was found for trees with a diameter of 30 cm DBH or more. Thus forest fires have a large impact on the composition of canopy and emergent trees species. Logging affected species composition in two ways. As expected, one year after logging, a shift in species composition was found for trees having a diameter of 50 cm and more (these are the timber trees). Unexpectedly, this compositional shift becomes even larger in forests that were logged 15 years and 25 years ago. Thus logging can have a significant effect on the future composition of canopy and emergent tree species (the future timber species), as compared to the species composition in primary forest. Moreover, a large compositional shift was also found for trees with a diameter of between 10 and 30 cm DBH. This shift is mainly caused by a larger in-growth of small (trees with a diameter < 10 cm) understorey tree species. We could not detect a significant increase in the number of pioneer species for these stem diameter classes (10-30 cm DBH) in logged forests as compared to primary forest.

This preliminary analysis was carried out on only 6 plots, each having a sample area of 1.5 ha. In order to generalise these results we should also analyse species composition in plots from different regions in Kalimantan. However, species composition is also likely to be site-specific, because of the occurrence of regional patterns in species distribution. A better way of generalising patterns in compositional changes of species assemblages caused by disturbance might be to assign species to plant functional types. To do this would require additional information on tree characteristics such as wood density and seed size. After species have been assigned to groups, shifts in abundance of plant functional types as a response to disturbance can be modelled.

INTRODUCTION

Vast areas of primary rainforest in Kalimantan (Indonesia) today are being lost through exploitation, large-scale fires and conversion to agriculture. As a result, degraded vegetation types and secondary forests are replacing patches of species-rich lowland rainforest. Most countries in the tropics, including Indonesia, now carry equal or larger areas of secondary forests than of original primary forest (*e.g.,* Brown and Lugo, 1990). It is therefore becoming increasingly important not only to protect and conserve patches of remaining primary forest, but also to investigate the possibilities of recovering the original biodiversity levels of secondary forests.

In late successional forests, small-scale disturbance, caused by tree fall, provides gaps in which early successional species (*i.e.,* pioneer species) can fulfil their growth cycle. In addition, landslides and erosion may cause natural large-scale disturbance (*e.g.,* Richards, 1996; Whitmore, 1989, 1991). Disturbance caused by human interference varies widely in scale, type and intensity. Such disturbance can range from gap formation caused by reduced impact logging to large-scale and repetitive slash and burn activities. Because type and intensity of disturbance varies, an array of degraded vegetation types follows, varying in structure and species diversity (*e.g.,* Finegan, 1996). Disturbed vegetation types are not static, so they may recover from disturbance (Brown and Lugo. 1990; Riswan and Kartawinata, 1991; Whitmore, 1991; Terborgh and Petren, 1991; Finegan, 1996; Miller and Kauffman, 1998). For example, reduced impact logging may cause only localised damage and result in gap formation (*e.g.,* Whitmore, 1991). If the gaps are not too large, forest patches can quickly regenerate through secondary succession and the original vegetation can recover. At the other extreme, fire, clear cutting, and shifting cultivation (*e.g.,* slash and burn activities) usually result in much larger areas of degraded vegetation. When, in addition, disturbance is frequent, through continued human interference, the vegetation will consist solely of *Imperata* grasses (*e.g.,* MacKinnon *et al.*, 1996; Richards, 1996). Such vegetation might also recover from disturbance, but only after human pressure has ceased and after a long period of time (MacKinnon *et al.*, 1996; Finegan, 1996).

A unique feature of lowland climax rainforest of Southeast Asia is that a single plant family, notably the Dipterocarpaceae family, accounts for many of the large trees (emergents), and hence this lowland rainforest is called Mixed Dipterocarp Forest (MDF) (*e.g.,* Whitmore, 1989, 1991; Schulte and Schöne, 1996; Richards, 1996). As in all tropical lowland rainforests of the world, total species richness in MDF is high. Whitmore (1989, 1991) reported, between 150 and 175 different tree species per hectare amongst trees of ≥ 10 cm DBH. Secondary forests, on the other hand, have fewer species. This is partly from the result of environmental conditions in secondary forests which promote growth of early successional pioneers, of which there are fewer species (Richards, 1996; Whitmore, 1989, 1991).

Species diversity in secondary forests may increase as the forest patches develop, so that eventually the high species diversity of late successional MDF can be reached. The question then arises of whether predictions can be made from forest inventories about the development of species diversity from disturbed secondary forest patches to late successional forest.

AN EXAMPLE OF THE DATA ANALYSIS

A number of forest inventory databases are available for analysis within the MOFEC-Tropenbos programme. These databases contain species lists and tree diameter measurements (DBH) only. If model predictions are to be made on the shifts in species composition caused by disturbance, we need first to analyse the underlying processes causing these shifts. After disturbance, gaps are created where large old trees have disappeared and in which new trees can invade. The higher light levels created by gaps may cause increased growth rates for understorey tree species, as well as more favourable germination conditions for the seeds of pioneer species. The recovery of a forest patch is driven by secondary succession. Succession is the process of 'species turnover', which leads to changes in vegetation cover and type (*e.g.,* Usher, 1992, see Figure 1).

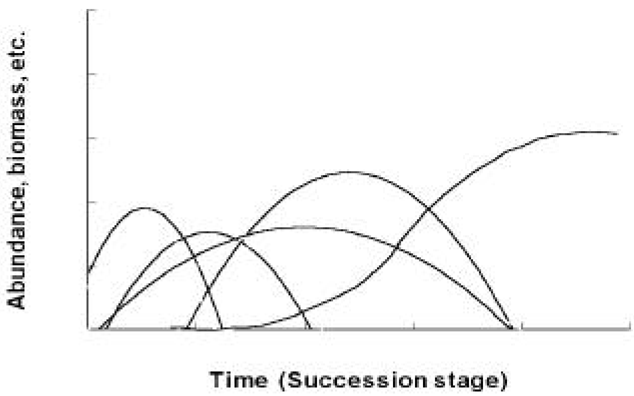


Figure 1 A hypothetical sequence of a number of species, species groups, guilds or plant functional types (PFT) during succession. (*e.g.*, Usher, 1992).

In the case of secondary forest succession, do tree species already present in the forest 'reclaim' the gap created by disturbance or do we find new species? As the new stand develops, species composition may further deviate from the original species association. Sheil (1999) introduced a method for analysing some temporal aspects of succession. The rationale behind this method is that big stems reflect the past composition of small stems (Sheil, 1999). Using this size-structured analysis, we studied the changes in species composition of trees belonging to various stem diameter classes. Sheil (1999) used a multivariate technique called Detrended Correspondence Analysis (DCA, *e.g.,* Hill and Gauch, 1980; ter Braak, 1985). In short, a Correspondence Analysis comprises an Eigen analysis, in which a similarity matrix of cases (plots) and variables is produced, based on chi-square distances, by the column and row totals of the matrix. Plots are arranged along the axes according to the variation explained in the data. Thus axis 1 explains the largest variation and subsequent axes residual variation. A Detrended CA is different in that it corrects for a major defect of ordination methods called the 'Arch' or *e.g.,* Hill and Gauch, 1980; ter Braak, 1985). Sheil (1999) was able to arrange plots along the first DCA axis according to their 'successional status', and showed that species composition in early successional forest largely differed from late successional forest depending on the stem diameter of the trees analysed. This difference depends on the time that has elapsed since disturbance, the speed of succession, growth of pioneer trees and local growing conditions.

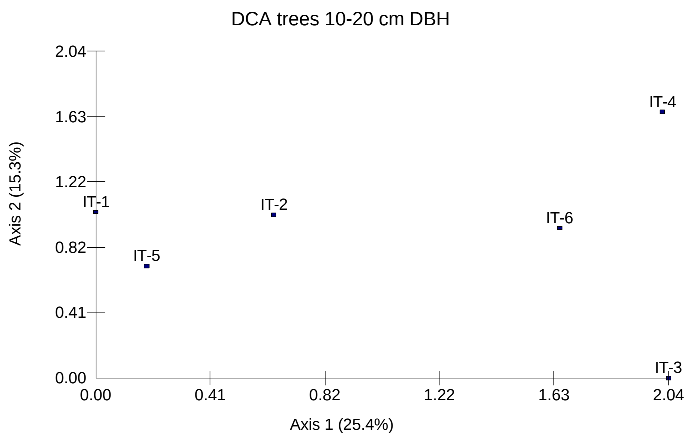
We examined the species composition of different primary and secondary forests from a large forest inventory database containing information on tree species abundance and diameter measurements of trees from different localities in East Kalimantan. For the analysis shown here we used data from one locality only. A detailed site description of this locality can be found in Slik *et al.* (in prep.). The inventory concerned was carried out in the International Timber Corporation Indonesia (ITCI) concession (see Table 1).

Table 1 The 6 plots in the ITCI concession. IT-1 is primary forest, while IT-2 through IT-6 are plots in disturbed secondary forests. The location, total sampled area (in hectares), species diversity (Fishers α, Fisher *et al.*, 1943, Taylor *et al.*, 1976), number of stems (trees ≥ 10 cm DBH) and number of tree species (stems ≥ 10 cm DBH) are given for each plot.

Plot	Type	Location	Area	Fishers α	Stems	Species
IT-1	Primary forest	116°26' E; 0°52' S	1.5	96.1	523	179
IT-2	Logged 1 year ago	116°21' E; 0°52' S	1.5	68.8	325	120
IT-3	Logged 15 years ago	116°31' E; 0°55' S	1.5	105.6	596	200
IT-4	Logged 25 years ago	116°35' E; 0°53' S	1.5	98.3	581	190
IT-5	Primary forest, burnt 1 year ago	116°27' E; 0°48' S	1.5	65.5	376	125
IT-6	Logged 15 years ago, burnt 1 year ago	116°30' E; 0°51' S	1.5	94.0	411	158

Five replicate plots (each 30 x 100 m) were laid out for each forest type (primary forest and secondary forests disturbed by logging and by fire), giving a total sampling area of 1.5 hectare per forest type (table 1). For the logged plots, logging intensities varied around 10 trees per ha (MacKinnon *et al.*, 1996). All trees ≥ 10 cm DBH were identified in each forest type and their diameters measured. To study the recovery of the vegetation and thus changes in species composition as affected by disturbance, we analysed species composition in different forests per stem diameter class. Stem diameter classes were assigned per 10 cm interval, starting from 10 cm DBH. The largest diameter class comprised stems of 60 cm DBH and larger. We expected that species composition in logged plots would differ largely from primary forest for small diameter classes. This difference would be smaller in the 25 year-old logged forest than in the 15 year-old logged forest, because species composition in 25 year-old logged forest would gradually converge to that typically found in primary forest. We could not test the same hypothesis for secondary forests disturbed by fire, since we had data only for secondary forests disturbed by fires one year ago. We therefore analysed only species-specific mortality patterns caused by fire for different stem diameter classes.

We expected plots to be ordered according to disturbance history and type. For the ordination we used stem counts per species. Species for some genera could not be identified. These individuals were grouped per genus. Typical ordination patterns are shown in Figure 2 for stem diameter classes 10-20 cm and for class ≥ 60 cm DBH. We interpreted plot position along axis I of the DCA as a ‘successional score’ (*i.e.*, Sheil, 1999). An ordination was performed for each stem diameter class and Figure 3 shows the axis I scores of plots for all stem diameter classes. The effects of fire on the mortality of tree species for different stem diameter classes can be studied by comparing plots IT-5 (primary forest disturbed by fire) with IT-1 (primary forest), and plots IT-6 (secondary forest logged 15 years ago and disturbed by fire) with IT-3 (forest logged 15 years ago). For both primary and logged forest, the effect of fire on species composition is relatively small for trees in diameter class 10-20 cm DBH, but much larger for trees in class 20-30 cm DBH. The largest differences were found in stem diameter classes 30-40 and 40-50 cm DBH, which include understorey and sub-canopy trees (Figure 3). For class 30-40 cm DBH, this difference was much larger for primary forest disturbed by fire than for logged forest disturbed by fire.



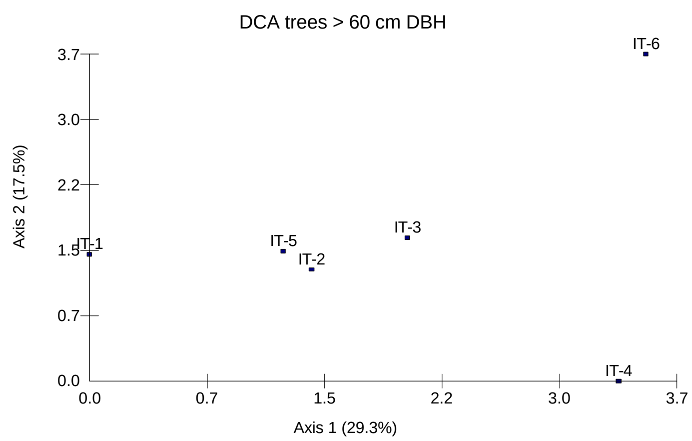


Figure 2 Detrended Correspondence Analysis of plots from the ITCI concession for stems between 10 and 20 cm DBH (top) and for stems ≥ 60 cm DBH (bottom).Only the first two axes are shown for both graphs. For explanation of plot codes (IT-1 to IT-6) see Table 1.

Among the logged plots, we expected that plot IT-2 (logged 1 year ago) would show the smallest deviation from primary forest for all stem diameter classes. Plot IT-2 did indeed have the most comparable species composition with primary forest among the logged plots, but the compositional shift from primary forest was greater for large diameter classes (50-60 and ≥ 60 cm DBH). This may be the result of the selective removal of timber trees belonging to these diameter classes. We found two large compositional shifts in the logged plots IT-3 and IT-4 (15 years and 25 years after logging, respectively). The largest deviations from primary forest were found for diameter classes 10-20 cm and 20-30 cm, and for diameter classes 50-60 cm and ≥ 60 cm DBH. Thus logging caused a compositional shift from primary forest for understorey, canopy and emergent trees, while the larger understorey and sub-canopy tree composition showed little change. Because this shift becomes even larger in plot IT-4 (logged 25 years ago), we expect logging to have a large temporal effect on the future species composition of large canopy and emergent species.

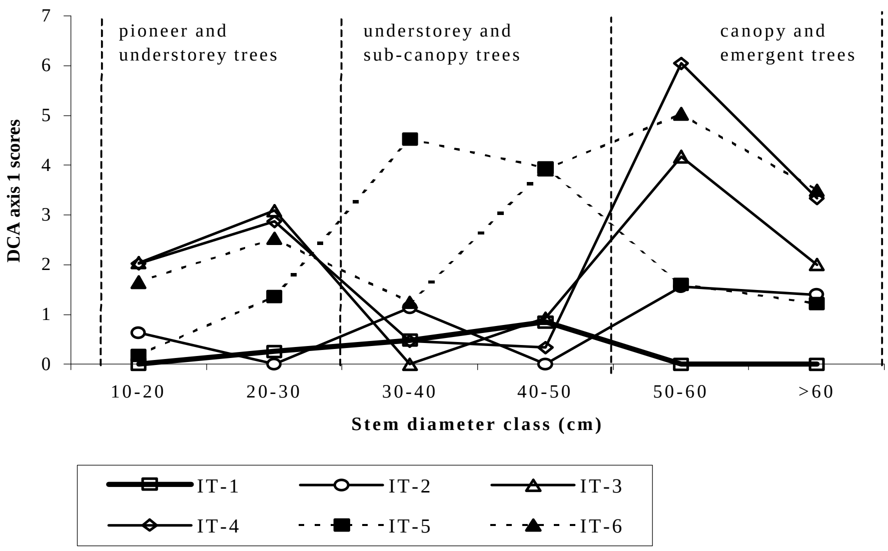


Figure 3 The position of plots from the ITCI concession along the first axis of the Detrended Correspondence Analysis for each stem diameter class. For explanation of plot codes (IT-1 to IT-6) see Table 1. Black symbols connected with dashed lines include fire-affected plots, open squares connected with thick lines primary forest and open circles, triangles, and diamonds connected with lines include logged forests.

Pioneer species like *Macaranga pearsonii* and *M. gigantea* can grow up to an average DBH of 21 and 28 cm, respectively, in 25 years (Slik, pers. obs.). We expected to find a larger number of pioneer species in diameter classes 10-20 and 20-30 cm DBH in logged forest as compared with primary forest. However, for diameter classes 10-20 and 20-30 cm DBH, we did not find a significant difference in the number of pioneer trees between the logged plots and the primary forest plot (Table 2). Thus this compositional shift in logged forests may be due to a stronger in-growth of understorey tree species rather than a larger invasion of pioneer species . These small understorey trees could well be future sub-canopy, canopy or emergent species.

Table 2 The number of pioneer and non-pioneer species (as % of the total number of tree species) for stem diameter classes 10-20 and 20-30 cm DBH for the plots in primary (IT-1), 2 year-old logged (IT-2), 15 year-old logged (IT-3), and 25 year-old logged forest. Pioneers include all species defined as 'species found in secondary forests' (Keßler and Sidiyasa, 1994). Distribution of pioneer and non-pioneer species in different logged plots did not differ significantly from the distribution in primary forest (Chi-square test with Bonferoni correction for multiple comparisons).

	10-20 cm		**20-30 cm**	
Plot	Pioneers	Non-pioneers	Pioneers	Non-pioneers
IT-1	27	73	17	83
IT-2	25	75	20	80
IT-3	29	71	31	69
IT-4	33	67	25	75

MODELLING SECONDARY FOREST SUCCESSION

Although our preliminary results on the species compositional shifts due to disturbance seem straightforward, it should be noted that it is difficult to generalise from these results, since we analysed only 6 plots at one locality. In a first database survey we carried out a DCA in which plots from different regions of East Kalimantan were put into one ordination (data not shown). We expected plots of disturbed forests to have a similar ranking to that shown in Figure 3, while regional differences in species composition could affect the plot ranking along subsequent axes. However, regional differences in species composition affected plot ranking along the first three axes of the DCA. This implies that an analysis of species composition as affected by disturbance may only be analysed per floristic region, because species assemblage may differ widely between different regions. Indeed, types can differ considerably among secondary forest vegetation, depending on local site conditions as well as on disturbance type (*e.g.*, Laumonier, 1997). This may have significantly affect the modelling of secondary succession based on changes in species composition only.

Simulation models have proved to be useful tools for predicting the effects of large-scale disturbance on both ecosystems and their recovery (*e.g.*, Heil and Bobbink, 1993; van Deursen and Heil, 1993; Moilanen and Hanski, 1995; Deutschman *et al.*, 1997). One way to understand the process of secondary forest succession is to develop a simulation model, because this forces us to formalise ecological processes and therefore increases our understanding of how disturbance acts on the functioning of ecosystems. Moreover, simulation models also provide results which can support policy making, such as in land-use planning.

In modelling secondary forest succession, we should look at changes in the functional aspects of the forest rather than to try to model changes in species lists. For the purposes of this model, species are usually assigned into different plant functional types (PFT, *e.g.*, Condit *et al.*, 1996; Lavorel *et al.*, 1997). Classifying tree species into different functional types requires additional information on tree characteristics and life history parameters. Information such as growth and mortality rates, wood density and seed size can be used as proxy parameters for species assemblages in a model. Unfortunately, such information for tree species from Kalimantan is rare and, where it is available, rather scattered through the literature (but see Raich and Gong, 1990; Suzuki, 1999). We are currently carrying out both a literature survey and additional measurements on such plant parameters to add to the species lists.

A number of model types are now available which deal with the simulation of forest succession (West *et al.*, 1981; Bossel, 1991; Huston, 1992; van Hulst, 1992; Usher, 1992; Bossel and Krieger, 1994; Köhler and Huth, 1998; Givnish, 1999). Moreover, within the last few years, these models have become based more on individual trees - (*e.g.*, Bossel, 1991; Huston, 1992; Urban and Shugart, 1992; Bossel and Krieger, 1994; Köhler and Huth, 1998; Chave, 1999). In our study, we may treat different plant functional types as individual trees and model changes in abundance of PFTs as affected by disturbance. A next step is to develop the model in such a way that changes in species groups (PFTs) as affected by disturbance and regrowth are extrapolated to a larger spatial scale (*i.e.*, at a landscape level). This requires information on habitat distribution and patchiness (*i.e.*, habitat fragmentation) over a landscape, since the possibility and speed of recovery of disturbed forests depends on the presence of nearby forest patches to serve as sources for new trees. This information can be derived from Remote Sensing (RS) satellite images. Changes in fragmentation of forest patches through time can be analysed from RS images and may give land-use planners information on the possibilities for recovery of secondary forests.

ACKNOWLEDGEMENTS

We thank Hans Ter Steege for his stimulating discussions on the various topics addressed in this paper.

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BIODIVERSITY TRANSIENTS IN DEGRADING AND RECOVERING MOSAIC LANDSCAPES

Cees J. Nagelkerke

ABSTRACT

Tropical forest landscapes generally consist of a mosaic of habitat patches with different disturbance characteristics. Anthropogenic degradation may drastically change the frequency distribution of the different habitats or alter their disturbance rates. I use metapopulation theory to model the fate of ensembles of species that inhabit such mosaic landscapes. Species differ in their habitat needs and a central assumption is that dispersal behaviour is moulded by natural selection. This results in a dispersal rate that increases with the pristine disturbance rate of the habitat patches on which a species depends. The speed with which population levels react to changes in the amount of suitable habitat therefore also increases with the disturbance rate. Consequently, when frequently disturbed habitat types become relatively more abundant regionally, the increase in number and density of disturbance-dependent species is much faster than the decrease in species in the declining, more stable habitats. Landscape degradation may therefore result in a temporary increase in regional biodiversity before a lower equilibrium is reached. When the landscape is allowed to recover, a temporary decrease in biodiversity may occur. Hence, there can be a marked asymmetry in the reaction to degradation compared with recovery. When degradation leads to an increased disturbance rate for all habitats, however, species from the originally most stable habitats suffer the greatest and fastest decline. Accordingly, there is little asymmetry between degradation and recovery. The biodiversity "debts" and "credits" studied here can arise without there necessarily being any competitive interactions between species. Time lags, as studied here, are expected to be of major significance for the future of biodiversity in tropical forests.

INTRODUCTION

I investigate how the biodiversity of a whole landscape will change in reaction to various kinds of landscape change, and how fast those changes will occur. The work is theoretical, using mathematical and computer models.

I address two important theoretical needs of conservation biology. The first need is to take a multitude of species and habitats into account; this is crucial when studying biodiversity change. Most existing work is on one species or on one habitat. The second need is to study time-delayed processes in the reaction to environmental degradation. An example is the occurrence of extinction debts, i.e. the continuing existence of species that are doomed to extinction.

Time delays in the reaction of biodiversity to changed circumstances are of major importance because they may determine how much extinction or other ecosystem change is awaiting us. Habitat destruction, especially of tropical forests, is generally seen as the dominant threat to biodiversity (e.g., Pimm *et al.*, 1995; Pimm, 1998). Recorded species extinction, however, is much less than what would be expected theoretically (Heywood and Stuart, 1992; Whitmore, 1997). Some authors therefore reason that the predictions are too pessimistic (e.g., Budiansky, 1994). Others argue that extinction takes place with a delay and that many extant species are doomed (e.g., Heywood *et al*., 1994; Whitmore, 1997; Pimm, 1998).

As yet, very little is known about time lags. Hardly any theory is available and estimates about the time taken by extinction differ widely. For example, Brooks *et al.* (1999) claim a time scale of about 50 years for birds in tropical forest fragments, whereas Kellman *et al.* (1996) argue that 10.000 years is too short for trees, but 20 million too long.

It is therefore extremely important to investigate the generality, magnitude, time rates, and exact mechanisms of time-delayed biodiversity changes. For example, how do they differ between organisms, landscapes and kinds of degradation?

Degradation results in natural habitats becoming fragmented and alters their disturbance dynamics. Disturbance frequencies often increase. Whereas rather stable patches predominate in “pristine” systems (Figure 1a), anthropogenic degradation often results in a drastic shift in the distribution of disturbance towards the more often disturbed patch types (Figure 1b). One way of studying the effects of such changes is to analyse the landscape as being inhabited by subpopulations distributed over habitat patches, which together form a metapopulation (Levins, 1969). This approach assumes a collection of habitable patches embedded in an uninhabitable, but permeable matrix. Moreover, local populations in patches have a limited lifetime, some migration between patches is possible, and the balance between colonisation and extinction determines how large a proportion of the patches will be inhabited at one time. Consequently, the dispersal rate between patches and the rate of local population extinction are crucial parameters. When patches become too isolated, or local extinction rates too high, metapopulations may become extinct. Because many populations are naturally fragmented, metapopulation theory can also be applied to the analysis of more natural situations (e.g., Hanski and Gilpin, 1997). Recently, a metapopulation approach has also become prominent in analysing the influence of degradation on the biodiversity of tropical forests. Because many tropical species are specialised, rare, patchily distributed, and bad dispersers (Laurance, 1994), metapopulation structures are thought to be common.

However, existing metapopulation approaches have two main shortcomings for investigating the effect of landscape degradation, especially of species-rich landscapes: (1) only one species is treated at a time and (2) patches have only two possible characteristics (habitable or not habitable).We obviously need to take a multitude of species into account when studying biodiversity, especially in the species-rich tropics. We have to focus on biodiversity, while retaining the realism of the metapopulation approach. Moreover, two states – hospitable *vs.* inhospitable, often equated with “undisturbed” *vs*. “disturbed” – will often not be an adequate habitat description. In reality, there will be a range of habitats differing in disturbance characteristics, while species also differ in their tolerance of, or dependence on, disturbance. The problems we are interested in relate not so much to how one particular species will react to the fragmentation of its habitat, as to how the biodiversity of a landscape will react to degradation that causes a change in the distribution or frequency of disturbance. In order to address these shortcomings, I investigate a multi-habitat landscape inhabited by a range of species, but analyse the individual species as metapopulations. This makes it possible to investigate the influence on biodiversity of different types of landscape degradation.

Landscapes are modelled that consist of a mosaic of habitat patches with different disturbance frequencies. (Figure 1a). Disturbance is a fact of life, but some habitats will be seldom disturbed, whereas others will be disturbed frequently. Metapopulation theory is adapted to model the fate of an ensemble of species that inhabit such mosaic landscapes and that differ in their reaction to disturbance. Each species is assumed to depend on a given habitat type (Figures 1c and 1d). Because disturbance frequencies depend on the type of habitat, species differ in the frequency of local extinction they experience. Some species will live in very stable habitats, but others in habitats that have a high disturbance frequency. It is assumed for simplicity that each species can use only one kind of habitat and that species do not interact. I first study the effects of different kinds of impact on single species, and then apply the results to the multitude of species in a mosaic landscape.

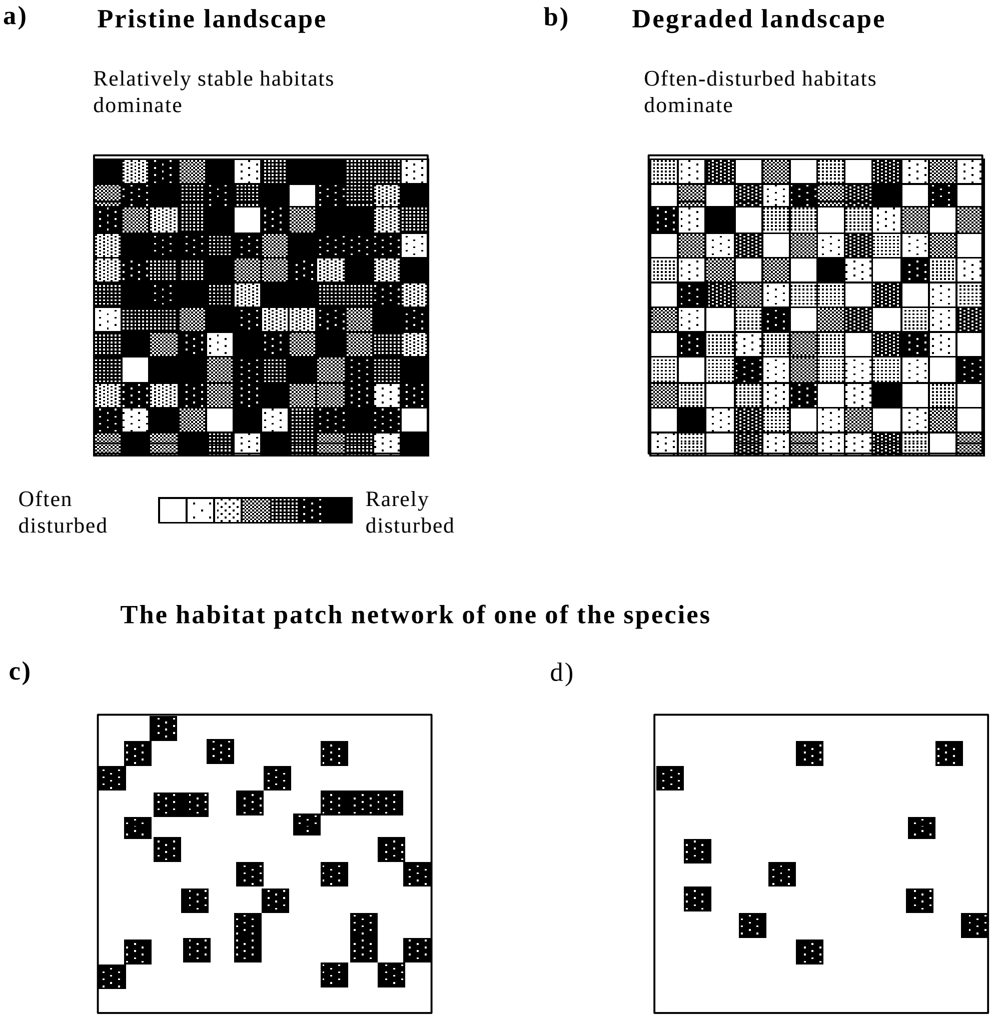

Figure 1 The landscape as a mosaic of different habitats that vary in disturbance rate. (a) pristine landscape, (b) degraded landscape, (c) and (d) the habitat network of one species in the pristine (c) and the degraded (d) landscape.

TIME LAGS IN INDIVIDUAL METAPOPULATIONS

To analyse individual metapopulations I use the classical Levins model (Levins, 1969), which has the form

$$(dn(t))/(dt) = cn(t)(N - n(t)) - en(t) \qquad (1)$$

where occupancy $n(t)$ is the density (or number) of occupied patches at time t, N is the total density of patches, c is the colonisation rate, and e is the extinction rate for an occupied patch. The equilibrium occupancies $n*$ are

$$n* = N - e/c \qquad (cN > e) \qquad (2a)$$

and

$$n* = 0 \qquad (cN ¾ e) \qquad (2b)$$

Hence, when $cN > e$ the metapopulation is viable; when N drops below e/c the metapopulation becomes extinct.

Metapopulations react with a time delay to landscape changes, such as habitat destruction (decreasing N) or increased disturbance (increasing e) that change the equilibrium occupancy $n*$. The reason is that the basic processes responsible for metapopulation dynamics, local colonisation and extinction, take time. For example, at an extinction rate of e = 0.01, the mean time to local population extinction equals $1/e$ = 100 years. A subpopulation may persist for tens or even hundreds of years before becoming extinct. Since the dynamics of the whole metapopulation is determined by the balance of colonisation and extinction, the approach of the new equilibrium may be slow. I define *return time* as the time it takes to reduce a deviation from an equilibrium value by 50%. This is used as a measure of the time lag. A large return time means a slow reaction.

To construct a general theory, I make assumptions about the dispersal behaviour of the individual species, using optimality arguments based on habitat requirements and the pristine landscape. In other words, the species are assumed to be adapted to the pristine landscape. I use the simple evolutionary relationship, according to which the optimal rate of dispersal $d*$ is equal to the local extinction rate e (van Valen, 1971). I then translate dispersal rate d into c with a scaling factor a, hence, $c = ae$. The value of a will depend on factors as fecundity and dispersal ability. I let e equal the habitat disturbance rate. This results in a dispersal rate that increases with the pristine disturbance rate of the habitat patches on which a species depends. Such a correlation between disturbance and dispersal is in agreement with field data (Southwood, 1962; Roff, 1990). Note, however, that a high "intrinsic" extinction rate, due for example to small population size, will have the same effect as high habitat disturbance. A further assumption is that evolution is slow compared with habitat change. Hence, the evolved dispersal rate does not change during habitat deterioration. I used analytical and computer models to investigate the speed of reaction of metapopulations of species from habitats that differ in pristine stability (measured by e).

I first describe the results for habitat destruction (decreasing N). Then, for as long as the amount of available habitat does not differ between species, return times will always *decrease* with increasing e. Species from habitats with a high/low disturbance rate, will react rapidly/slowly to changes in the amount of habitat. This is intuitively appealing. For example, we expect weeds to react quickly to increased opportunities. Clearly, there are “slow” species and “fast” species, and reaction speed correlates with the disturbance rate of the habitat. Slow species live in relatively stable habitats and react with a long time lag to changes in the amount of habitat.

I next consider the effect of increasing the disturbance rate *e*. The speed with which doomed species approach extinction then *decreases* with increasing pristine disturbance rate, contrary to the effect of habitat destruction. The added disturbance causes the originally slow species to become the faster ones. This implies that species from, originally, relatively stable habitats become extinct sooner. The reason is that their evolved low colonisation rate is easily swamped by an increase in local extinction rate.

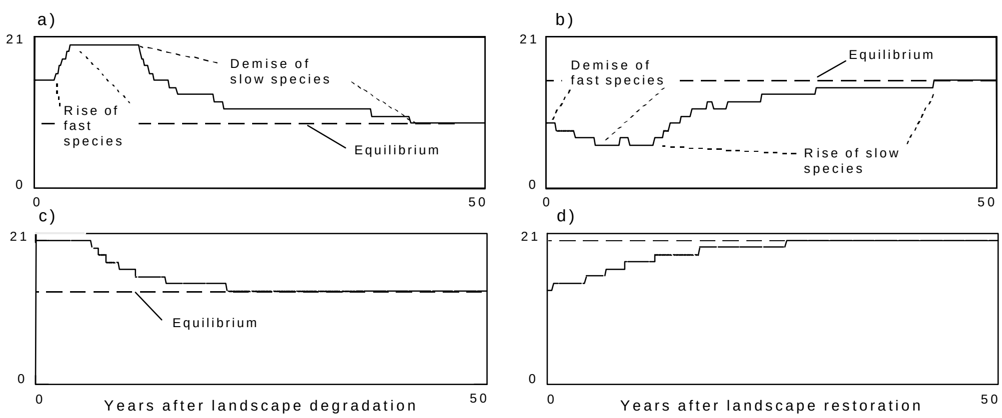

Figure 2 Total number of species over time in a mosaic landscape after different modes of landscape degradation and restoration. There are 20 habitats with pristine disturbance rates ranging from 0.05 to 1.0 per year. Every species has a metapopulation in its own habitat network. There is only one species for every habitat, and species do not interact. Landscape changes are applied suddenly and some immigration from outside is allowed. (a) Changing the relative amounts of the different habitats towards habitats with a high disturbance rate (e.g., from Fig. 1a to Fig. 1b). (b) Restoring the original habitat distribution. (c) Applying a general increase (of 0.6 per year) in disturbance rates. (d) Restoring the original disturbance rates.

TIME LAGS IN MOSAIC LANDSCAPES WITH MULTI-SPECIES COMMUNITIES

Using the models described above, we can predict the reaction of a whole assembly of species when a landscape degrades or is allowed to recover. I first investigate the effect of changes in the relative amounts of the different habitats. A pristine landscape will be dominated by relatively stable habitats, whereas a degraded landscape will have more habitat that is often disturbed (Figure 1a, b). After degradation, species from more stable habitats will decline or become extinct, because their habitat diminishes, whereas species from often disturbed habitats benefit. However, the increase in the fast, disturbance-dependent, species will occur at a faster rate than the decline of the slow species from the more stable habitats. This results in a temporary increase in diversity (Figure 2a) by immigration, before the number of species settles at its new, lower equilibrium. Because many species from more stable habitats will disappear only after a delay, there is an “extinction debt”. By contrast, after restoration, a “colonisation credit” appears (Figure 2b). The number of species then decreases temporarily before rebounding to its pristine level. The fast species react quickly to the decline in their habitat, whereas the slow species return only after a delay. Clearly, there is a strong asymmetry between degradation and recovery.

A general increase in the disturbance rate causes declines in occupancy for all species. Species from the originally most stable habitats suffer the most and, contrary to the effect of habitat destruction, they are also the ones that decline the fastest. There are now no temporary increases or decreases in the number of species (Figure 2c and 2d) and there is little asymmetry between degradation and recovery. Whereas species that were formerly the slowest, are now the first to disappear, they are also the last to reappear when the disturbance rate returns to the pristine value.

DISCUSSION

Prediction of the development of biodiversity over time after landscape change requires an insight into the differences between species in strength and speed of reaction, followed by integration into a multi-habitat/multi-species analysis. This necessitates a refocusing from a one-species to a multispecies view, contrary to most metapopulation ecology, and also a mosaic vision which differs from the “habitable-island-in-an-uninhabitable-sea” approach of classic island theory.

Using metapopulation models and assumptions about the evolution of dispersal behaviour, it is possible to predict how species from different habitats will react. The pristine disturbance frequency of the habitat of a species (and hence local extinction rate) and type of degradation are important determinants. Species from stable habitat will react more slowly to changes in the amount of habitat than species from a frequently disturbed habitat. One consequence is that, after broad spectrum habitat destruction, we expect a higher prevalence of doomed species in the more stable habitats. When the disturbance rate is increased, however, species from originally stable habitats disappear rapidly, but recover slowly after eventual restoration.

The results show that time transients due to metapopulation dynamics emerge as a prominent feature in the reaction of biodiversity to environmental changes. Delays in metapopulation reaction and differences between species in speed of reaction give rise to transients in regional biodiversity. The work reported here provides an insight into the form and structure of those transients. After degradation an “extinction debt” may appear; many species are still there that will surely disappear after a delay. Hence, current biodiversity patterns actually may be transient when landscape change occurs faster then metapopulations can track. Many species may be “living dead” and protection of the current landscape may not guarantee long-time survival. However, the results also draw attention to the existence of another side of the time–lag coin which I call a “colonisation credit”; during recovery after landscape restoration many species may reappear only after a delay. The decline or rise in biodiversity need not occur monotonically. Temporary increases or decreases in number of species may occur that are not representative of what will occur in the longer term. Hence, there may be unwarranted optimism or pessimism. Note that a positive aspect of time lags is that, when properly identified, they may provide breathing space for remedial action. An important result is that there may be significant asymmetries between degradation and recovery. Recovery is not just degradation in reverse.

It is instructive that competition plays no role in the extinction debt. In a much discussed paper, Tilman *et al*. (1994) found extinction debts in a model that had strong competitive interactions between species. It is often assumed that these debts arose from the competitive interactions. But in my model there is no competition whatsoever. Debts do not arise from competition, but are a basic consequence of metapopulation dynamics.

Previously, time lags in the reaction of biodiversity to environmental change have mainly been studied empirically. The work reported here provides an insight into the fundamental mechanisms behind time lags, and into their form and structure. It opens possibilities for predicting how long time lags will be in different circumstances. Because recent environmental changes have been fast and much further degradation is expected, especially of tropical forests (Sala *et al*., 2000), time-delayed biodiversity changes will be crucial for the long-term fate of biodiversity. The study of their mechanisms, as attempted here, is therefore important. Delayed recovery processes also deserve investigation, as in some places, like Puerto Rico (Thomlinson *et al.*, 1996), tropical forests are making a comeback after severe former degradation.

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RESPONSES OF WOODPECKERS TO SELECTIVE LOGGING AND FOREST FRAGMENTATION IN KALIMANTAN – PRELIMINARY DATA

Martjan (J.M.) Lammertink

ABSTRACT

Woodpecker diversity, densities and foraging ecology are being studied in primary forests, logged landscapes (with primary and logged patches) and small forest fragments in West Kalimantan. Woodpecker species richness does not differ between primary forest and logged landscapes, but is lower in small forest fragments. Densities of woodpeckers in primary and logged landscapes do not differ significantly, although differences may become significant when more replica study sites of forest types have been established. Average densities over three primary and three logged sites are lower in logged landscapes for nine out of 13 woodpecker species. Within logged landscapes, eight out of nine woodpecker species are more abundant in primary patches than in logged patches. This preference for primary patches is significant for the Checker-throated Woodpecker *Picus mentalis*. The Checker-throated Woodpecker is a highly mobile forager of the lower storeys and its density is negatively correlated with the volume of dense foliage between heights of 0 and 15 m. Reduced impact logging should aim to avoid the creation of a dense understorey and to retain moist dead trees under the forest canopy. Primary lowland forest, which is important for conservation, science and tourism, has nearly disappeared in Kalimantan. Laws to protect primary forest reserves should be enforced more effectively.

INTRODUCTION

Woodpeckers form a nearly cosmopolitan bird family, comprising about 230 species. All woodpeckers share unique characteristics, such as a bill and skull structure specialised for pecking, stiff tail feathers, climbing feet and a long extendable tongue. These features enable woodpeckers to excavate tree cavities and to prey on wood boring or bark dwelling invertebrates.

Some woodpeckers are generalists and occur in a wide range of primary and disturbed habitats, while other woodpeckers are narrowly specialised, for instance, in foraging on dead or old trees. In several temperate and subtropical forest ecosystems, woodpecker species occur that are among the vertebrate organisms most sensitive to the effects of forest exploitation. Examples of woodpecker species that are obligate old-growth or primary forest specialists include the White-backed Woodpecker (*Dendrocopos leucotos*) and Middle Spotted Woodpecker (*Dendrocopos medius*) in Europe, the Red-cockaded Woodpecker (*Picoides borealis*) in North America, the Ivory-billed Woodpecker (*Campephilus principalis*) in Cuba and North America, and the Imperial Woodpecker (*Campephilus imperialis*) in Mexico (Winkler *et al*., 1995). The latter two species are now actually extinct as a consequence of the selective logging of all the forests within their respective geographical ranges (Lammertink and Estrada, 1995; Lammertink *et al*., 1996).

The highest diversity of sympatrically occurring woodpecker species in the world is found in the lowland rainforests of Borneo, Sumatra and Peninsular Malaysia. In these tropical forests, the woodpecker community encompasses up to 14 or 15 species. Because of this high diversity, one may expect narrow specialisation and thus high sensitivity to forest disturbance by some of these Asian woodpeckers.

Figure 1 The Great Slaty Woodpecker (*Mulleripicus pulverulentus*)is the largest woodpecker in lowland forests of Borneo, where up to 14 or 15 woodpecker species occur sympatrically.

This paper is about a study on woodpeckers and forest disturbance that was started in West Kalimantan, in and near Gunung Palung National Park in November 1998. The project not only looks at the effects of logging and forest fragmentation on the diversity and densities of woodpeckers, but also studies the foraging ecology of woodpeckers and changes in forest structure after logging, in order to assess the causes of changes in woodpecker abundance. The study further attempts to elucidate the mechanism that drives niche partitioning within the woodpecker guild. An understanding of niche partitioning in this specialised guild may contribute to the effective use of the woodpecker guild as an indicator group.

In this paper I will address the following questions:

1) What are the differences in diversity and densities of woodpeckers between larger primary forest tracts and logged landscapes (with a mosaic of logged and unlogged patches)?
2) What are the differences in woodpecker densities between primary and logged patches within logged landscapes?
3) Do the microhabitat preferences of a declining woodpecker correlate with changes in forest structure?
4) What are the implications of the habitat requirements of sensitive woodpeckers for forest management?

METHODS

So far eight research sites have been established: three in primary forest, three in logged forest and two in small forest fragments (Figure 2, Appendix 1). All the sites were originally covered in swamp and lowland forests at altitudes of between 0 and 60 m, except for the primary forest site ‘Pb’, that includes hill forest up to 350 m. Forest fragments have been isolated for at least 50 years and are located several km from the nearest large forest block.

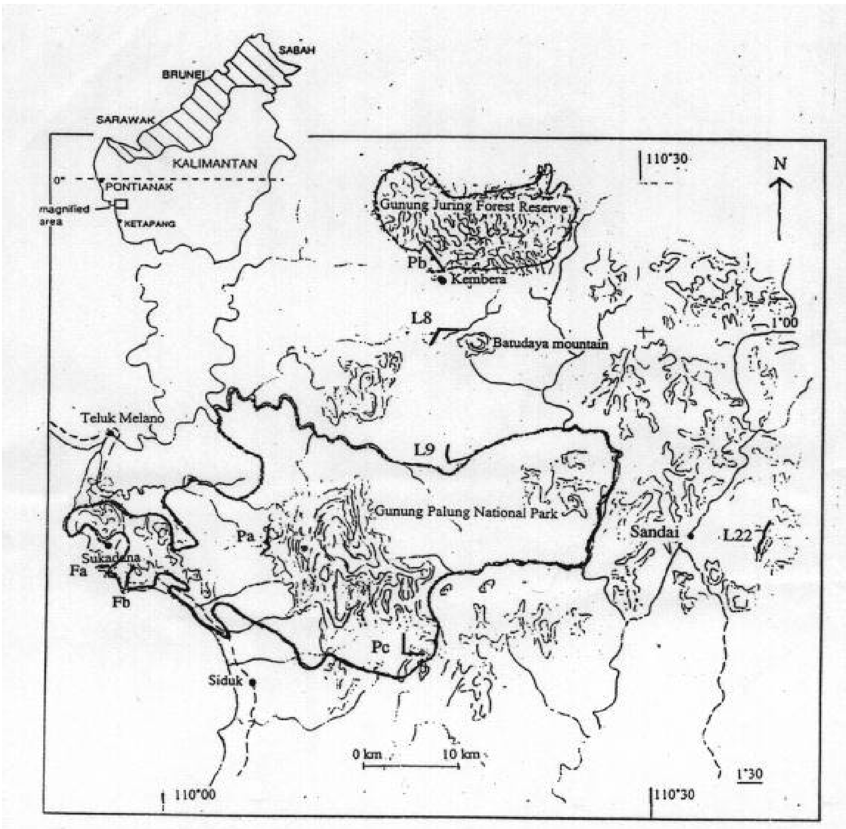

Figure 2 Map showing the location of eight study transects in West Kalimantan (see also Appendix 1).
Pa, Pb and Pc: primary forest sites
L8, L9 and L22: logged sites (numbers indicate years since logging)
Fa and Fb: small forest fragments of 90 and 150 ha, respectively

At most sites a transect of 4.4 km has so far been surveyed 12 times. It is proposed to establish more research sites with further replicas of the different forest types, and each transect will be surveyed for a total of 12 or 24 days. The aim is to maintain distances of at least 15 km between replicas and to have a spatial mix of different treatments, so that sites are as independent as possible.

A transect is walked with a standard speed of 50 m per five minutes (or 600 m per hour) and all bird observations, either sightings or bird calls, are entered on a map from which the perpendicular distance to the transect is taken. From this data set, densities are assessed using a variable belt width method (Emlen, 1971) or, when 60 or more observations are available, using the DISTANCE program. Not only woodpeckers, but all birds are surveyed, with special attention being paid to groups that previous research had found to be possibly sensitive to the effects of logging, such as trogons, wren-babblers, broadbills and pittas (Lambert, 1992; Johns, 1996). In this presentation, we will address only the responses of woodpeckers.

When a foraging woodpecker is encountered on a transect, the general bird inventory is suspended and a detailed protocol is completed in of the first minute of the foraging behaviour of the woodpecker., 28 forest structure plots have been studied along seven of the eight transects (Zekveld, 1999) to assess differences in availability of structural elements for foraging woodpeckers.

RESULTS

The transects that were cut in logged areas pass through a mosaic of logged and unlogged patches. Of the total transect lengths in logged landscapes, 5%, 22% and 52%, respectively, remains unlogged.The unlogged patches consist in general of swamp forest and the logged patches of dry lowland forest.

Table 1 Woodpecker species present in primary forests, logged landscapes (with primary and logged patches), and small forest fragments. Numbers after L indicate years since logging.

Woodpecker species	**Primary landscapes**			**Logged landscapes**			**Forest fragments**	
	Pa	Pb	Pc	L9	L8	L22	Fa 90 ha	Fb 150 ha
Picus puniceus	x	x	x	x	x	x		x
Blythipicus rubiginosus	x	x	x	x	x	x		x
Dinopium rafflesii	x	x	x		x	x		
Reinwardtipicus validus	x	x	x		x	x		x
Sasia abnormis	x			x	x	x		x
Celeus brachyurus	x	x	x			x	x	
Picus mentalis	x	x	x	x		x		x
Hemicircus concretus	x	x	x	x		x		
Dryocopus javensis			x	x	x	x		
Mulleripicus pulverulentus	x		x	x	x	x		
Meiglyptes tukki	x	x			x	x	x	
Meiglyptes tristis	x	x			x			x
Picus miniaceus							x	
TOTAL	11	9	9	7	9	11	3	6
n survey days	*12*	*12*	*7.6*	*9.5*	*12*	*12*	*12*	*8*

Woodpecker species richness is approximately the same in primary landscapes and logged landscapes, the latter forest type including logged and unlogged patches. In both forest types, 9 to 11 woodpecker species were found at sites where 12 survey days were completed. In the small forest fragments of 90 and 150 ha considerably fewer woodpecker species occur, i.e. three and six species, respectively (Table 1).

Densities of woodpeckers in primary and logged landscapes are presented in Table 2. The comparative densities between the two forest types is not significantly different for any of the woodpecker species (T test, $P > 0.05$). However, when average densities of woodpeckers in logged and unlogged landscapes are compared, nine out of 13 woodpeckers are rarer in logged landscapes. This is a higher number of declining species than would be expected by chance (χ^2, $P < 0.05$).

Table 2 Woodpecker densities in primary forests vs. logged landscapes (with primary and logged patches). Densities in individuals/km^2. PR is the preference ratio: the average ratio of densities in logged vs. primary landscapes, not taking into account empty cells. PR < 1 indicates lower average densities in logged landscapes.

Woodpecker species	**Logged landscapes**			**Primary landscapes**			**T test**	**Pr.**
	L9	L8	L22	Pa	Pb	Pc		
Celeus brachyurus			0.19	0.06	1.52	0.5	-	0.27
Picus mentalis	0.5		1.36	1.63	1.73	2.46	0.20	0.47
Dryocopus javensis	0.34	0.17	0.27			0.54	-	0.48
Reinwardtipicus validus		0.47	1.1	0.63	1.42	2.49	0.44	0.51
Mulleripicus pulverulentus	0.49	0.3	0.61	1.32		0.54	0.33	0.59
Meiglyptes tukki		0.76	1.14	0.76	1.89		0.63	0.71
Picus puniceus	0.4		0.53	0.95	0.32	0.5	0.58	0.78
Dinopium rafflesii		0.53	0.15	0.29	0.49	0.38	0.85	0.87
Hemicircus concretus	0.2		0.47	0.47	0.16	0.5	0.83	0.88
Sasia abnormis	1.41	1.14	3.41	1.52			-	1.30
Blythipicus rubiginosus	1.43	1.29	2.01	1.58	0.63	0.39	0.19	1.81
Meiglyptes tristis		0.96		0.32	0.63		-	2.02

Table 3 Woodpecker densities (individuals/km^2) in primary patches and logged patches within logged landscapes. Data refer to primary and logged patches of one forest type, dry lowland forest. PR is the average avoidance (< 1) or preference (> 1) of logged patches, not taking into account empty cells.

Woodpecker species	**Primary patches**		**Logged patches**			**T test**	**PR**
	PP9	PP22	LP9	LP8	LP22		.
Picus puniceus	0.79	5.56			0.15	-	0.05
Picus mentalis	4.27	4.76	1.47		1.26	0.03*	0.30
Celeus brachyurus	0.63		0.26		0.26	-	0.42
Meiglyptes tukki	2.12		0.79	0.48	1.58	-	0.45
Blythipicus rubiginosus	2.81	2.39	0.29	1.32	2.04	0.10	0.47
Dryocopus javensis	0.76		0.95	0.22	0.38	-	0.68
Reinwardtipicus validus	1.38		1.92	0.60	1.54	-	0.98
Mulleripicus pulverulentus	0.89		1.41	0.39	0.84	-	0.99
Sasia abnormis	2.84		4.72	0.97	4.21	-	1.16
Meiglyptes tristis			3.61	1.21		-	-
Hemicircus concretus			0.62		0.66	-	-
Dinopium rafflesii				0.68		-	-

The next step is a comparison of woodpecker preferences for primary or logged patches within logged landscapes (Table 3). Only primary and logged patches of one forest type, dry lowland forest, were used in this analysis. Because of the many empty cells in this data set, the difference can be tested for two species only. The Checker-throated Woodpecker (*Picus mentalis*) appears significantly more abundant in primary patches than in logged patches (T test, P < 0.05). The average preference ratio (Table 3, last column) shows a higher abundance in primary patches for eight out of nine woodpecker species, more than would be expected by chance (χ^2, P< 0.05).

The last columns of Tables 2 and 3 were combined in Table 4 in order to see if woodpeckers that are more abundant in primary landscapes also prefer primary patches within logged landscapes. For eight out of nine woodpeckers, the two preference ratios show a similar trend. The odd exception is the Maroon Woodpecker (*Blythipicus rubiginosus*), which is nearly twice as abundant in logged landscapes than in primary landscapes, but shows a strong preference for primary patches within the logged landscapes.

Table 4 A comparison of preferences for primary landscapes with preferences for primary patches within logged landscapes. Preference ratios taken from Tables 2 and 3. S means trend same for the two ratios, O means trend opposite for the two ratios.

	PR landscapes	**PR patches**	**Trend same or opposite?**
Celeus brachyurus	0.27	0.42	s
Picus mentalis	0.48	0.30	s
Dryocopus javensis	0.48	0.68	s
Reinwardtipicus validus	0.50	0.99	s
Mulleripicus pulverulentus	0.52	0.98	s
Meiglyptes tukki	0.72	0.45	s
Picus puniceus	0.79	0.05	s
Dinopium rafflesii	0.88	-	-
Hemicircus concretus	0.89	-	-
Sasia abnormis	1.31	1.16	s
Blythipicus rubiginosus	1.82	0.47	o
Meiglyptes tristis	2.02	-	-

Finally, we look at an example of a change in forest structure after logging that may cause the lesser abundance of one woodpecker: the Checker-throated Woodpecker. This woodpecker moves quickly through the forest when foraging, more quickly than any other woodpecker in Kalimantan. On average, the Checker-throated Woodpecker climbs 1.5 m per minute and flies 2.7 m per minute while foraging (n=62). It stays in the lower and middle storeys of the forest, at a height of between 4 and 15 m, with an average of 9.0 m (n = 62). The correlation coefficient between Checker-throated Woodpecker density and the volume of dense foliage at between 0 and 15 m is -0.74. In other words, this woodpecker avoids forests with dense undergrowth. Zekveld (1999) found a significantly higher volume of dense foliage in the lower layers of logged forests than in primary forests (Mann-Whitney test, P < 0.0001 for both the 0-3 and 3-15 m layers). The lower abundance of the Checker-throated Woodpecker in logged habitats is therefore probably due to a high volume of dense foliage in the lower forest layers, which hampers the foraging movements of this woodpecker.

DISCUSSION

The continued presence of most, if not all, woodpecker species in logged forests in Kalimantan is in contrast to some forest ecosystems in temperate and subtropical regions, where several woodpecker species disappear after disturbance (see introduction). One explanation for this difference may be that temperate forests are poor in tree species and a logging operation typically removes nearly all large trees. In contrast, in logged forests in Kalimantan, a considerable number of old-growth elements remain: large non-commercial trees, old trees with a hollow core, and strangler figs. Moreover, many unlogged patches remain in the logged landscapes studied here, making up between 5% and 52% of total transect length.

For an organism to be a perfect indicator for disturbance, it should be entirely absent from either disturbed or primary forests. None of the woodpeckers in Kalimantan meets this ideal and thus their value as indicators is limited. Nevertheless, no vertebrate organism has been found so far that disappears entirely from logged areas in Kalimantan (Johns, 1997; MacKinnon *et al*., 1997) and woodpeckers are no exception to this general finding. Instead, impact assessments will have to work with density responses for selected groups of organisms. The Checker-throated Woodpecker can be used for such an impact assessment by density tracking, as perhaps can other woodpecker species in Kalimantan for which the current data set is as yet insufficient.

More replica study sites of the two habitat types will be established during the remainder of this project and more surveys will be completed at each site. It may be expected that some of the densities of individual species in primary and logged landscapes will then show significant differences. It is apparent from Tables 2 and 3 that a large number of woodpeckers are, on average, less abundant in logged landscapes and, moreover, within these logged landscapes, most woodpeckers prefer primary patches. The similar trends shown in Table 4 of preferences for primary landscapes and preferences for primary patches in logged landscapes, indicates that it is indeed the presence of logged patches that causes the decline of many woodpecker species between primary and logged landscapes.

Johns (1996) found hardly any differences in species composition and densities of birds between primary and logged forests in Sabah. The study discussed here did find a decline for most species in at least one community, that of woodpeckers. This different finding may be due to differences in methodology. The present study uses longer transects, which are more suitable for assessing the densities of wide-ranging species such as some woodpeckers, while it also studies several widely spaced replicas of habitat types instead of single plots.

It may be argued that a decline to 30 or 50% of original densities for many woodpeckers in logged forests is not too worrying, provided that no species disappear altogether. However, selective logging is only the mildest form of forest disturbance in Kalimantan, and is more often than not followed by forest fires or clearance for plantations and agriculture. It is likely that many of the sensitive woodpeckers and other birds disappear with increasing degrees of forest disturbance, as is the case in the two forest fragments studied so far in this project. Moreover, a number of the birds of Kalimantan are confined to lowland areas and do not occur in the only reserves of any extent in Kalimantan, the hill forests of Bentuang Karimun and Kayan Mentarang.

The main recommendations for reduced impact logging resulting from this project are that the creation of a dense understorey should be avoided and that moist dead trees under the canopy should be retained. It is also of the utmost importance that large areas of logged lowland forest remain forested with native trees. These areas should not be burnt, and should not be converted to other forms of land use.

Another issue of forest management policy in Kalimantan where there is room for improvement, arguably the most important issue of all, is the lack of effective protection of the remnants of primary lowland forest. The lowland forests of Kalimantan are the richest in biodiversity (MacKinnon *et al*., 1997), yet the only national parks that include lowland forests are Kutai in East Kalimantan and Gunung Palung in West Kalimantan. Kutai National Park was burnt entirely in April and May 1998 (pers. obs.). Gunung Palung is a small park of 90,000 ha, of which only 60% is lowland and swamp forest. Nearly all of the lowland forest in the park is being illegally logged by hand (pers. obs.). At best, 15,000 ha of true primary lowland forest remains, the largest example of a nearly extinct ecosystem in Kalimantan. Another small patch of primary lowland forest is found in Sungai Wain, 15 km north of Balikpapan, which is vulnerable to encroachment and forest fires (Fredriksson, this workshop).

Some undisturbed tracts of lowland forest are needed in Kalimantan for the conservation of species that are primary lowland forest specialists, as a core habitat for most flora and fauna, as a reference for forestry researchers and biologists, and for ecotourism. The authorities should be aware that bird-watching is rapidly growing in popularity in Indonesia. The number of Indonesians wanting to visit primary lowland forests with a rich biodiversity may well grow into hundreds of thousands in the next 50 to 100 years. If, by that time, the lowland forests have all been destroyed, it is the present generation of decision makers who will be held responsible. Effective enforcement of laws that protect the few remnants of primary lowland forest is urgently needed.

ACKNOWLEDGEMENTS

Thanks are due to Pak Usnan, Pak Amsin and Udin for invaluable assistance in the field, to Corinthe Zekveld, Jeanine Lagendijk and Utami Setiorini for help with data collection, to Dr. Dewi Prawiradilaga and Prof. Steph Menken for support, to Mark van Nieuwstadt for advice, to LIPI Bogor and LIPI Jakarta for research permits, and to the NWO 'Biodiversity in Disturbed Ecosystems' programme for funding.

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APPENDIX 1 COORDINATES AND DESCRIPTIONS OF STUDY SITES

PRIMARY FOREST SITES

Pa: 'Cabang Panti', a long-term research station established by Harvard University in Gunung Palung National Park. About 2,000 ha of near-primary lowland forest at 50-60 m a.s.l. remains here, surrounded by a much larger area of lightly disturbed lowland forests to the north, west and south, and primary hill and montane forest to the east. Transect central point at 01°13'30"S

Pb: 'Kembera' in the Gunung Juring forest reserve. Primary lowland forest at 70- 100 m a.s.l. along 15 % of transect length, otherwise primary hill forests at 100 to 420 m a.s.l. Transect central point at 00°56'48"S 110°18'19"E.

Pc: 'Kepayang' in Gunung Palung National Park. Primary lowland forest at 60-80 m a.s.l., surrounded by lightly logged forest to the south, illegally handlogged forest to the east and west, and primary hill forest to the north. This area was illegally logged after completion of this study. Transect central point 160 m south of 01°19'43"S 110°14'05"E.

SELECTIVELY LOGGED SITES

L8: 'Batudaya' in the former Melant concession, logged 8 years previous to this study and with 78 % of the transect length logged. Swamp and lowland forest at 60 m a.s.l. Transect central point at 00°59'57"S 110°17'35"E.

L9: 'Matan' in the former Melant concession, logged 9 years previous to this study and with 49 % of the transect length logged. Lowland and swamp forest at 60 m a.s.l. Transect central point at 01°07'54"S 110°18'08"E.

L22: 'Sandai' in the still active Kawedar concession, 7 km east of the village of Sandai. Lowland forest on lightly undulating hills at 60-90 m a.s.l. This site was logged 22 years previous to this study and 96 % of the transect length is disturbed by logging. Transect central point at 01°13'55"S 110°36'56"E.

FOREST FRAGMENTS

Fa: 'Gunung Piatu'. A 90 ha forest fragment at 10-50 m a.s.l. of mostly secondary forest, old rubber plantations and durian gardens, and only 0.4.km of the 1.45 km transect through relatively undisturbed forest. Site approximately 3.5 km from the continuous forest of Gunung Palung National Park. Transect head at 01°15'20"S 109°57'15"E.

Fb: 'Gunung Peramas'. A 150 ha forest fragment at 10-40 m a.s.l. This hill is part of Gunung Palung National Park and is part near-primary forest (1.55 km out of the 3.6 km transect), part old ladang fields and durian gardens. Located 200 m from continuous forest of Gunung Palung National Park. Transect central point at 01°15'57"S 109°57'57"E.

THE USE OF FAUNA INDICATORS FOR MONITORING THE IMPACT OF DISTURBANCE; A REVIEW

Christiaan A. van der Hoeven and Hans H. de Iongh

ABSTRACT

This paper consists of a literature review of research on fauna indicators in Bornean lowland rainforests. The study concludes that, of the categories keystone species, threatened species, guilds and taxonomic groups, the guilds qualify best as potential indicators for human disturbance in the forest. The avian guilds are considered the most useful of the guilds, as there are extensive databases on birds, they are easy to observe and they can be identified from their vocalisations. Of the avian guilds, understory insectivorous birds seem to be most consistent for predicting disturbance in Bornean forests, but more research is needed to confirm the consistency of this finding. It is also concluded that survey methods are critical and determine the reliability of monitoring and assessment surveys. Standard protocols therefore need to be developed for Bornean lowland forests, using avian guilds and possibly other guilds (butterflies, primates) for back–up. In addition, the use of these protocols and indicators by stakeholders needs further study, but the authors conclude that the level of sophistication at present requires the input of professional ecologists and cannot be left to laymen. For further research, data on fauna indicators can be linked with successional stages of lowland forest after disturbance (fires, logging) in order to develop prediction models.

INTRODUCTION

The assessment of biological diversity has become increasingly important in the sustainable management of tropical forests. There is consequently a need to develop and implement monitoring systems with bio-indicators. These indicators are meant for monitoring and predicting changes in the diversity of the forest caused by human induced disturbance. This review will focus on fauna indicators, specifically on the island of Borneo, i.e. Brunei, the East Malaysian states of Sabah and Sarawak and Indonesian Kalimantan.

Biological indicators are widely accepted as a suitable approach for developing such a practical decision support system for forest managers, but little has been achieved to date in operational terms (CIFOR, 1999; ITTO, 1999).

The World Bank has published a paper on the monitoring and evaluation of biodiversity (World Bank, 1998). The selection of indicators is actually the last step before the design of a monitoring scheme. The World Bank paper is a useful guideline for the design and implementation of indicators. It describes the most desirable characteristics of indicators. These should:

- be cost-effective to monitor;
- be measurable;
- reveal meaningful trends.

The authors of this paper agree with the main characteristics and most of the considerations presented by the World Bank, but express doubt about the desirability of sampling by non-specialists. Even if only avian guilds are selected for monitoring and assessment, considerable knowledge and experience are a prerequisite for accurate identification.

It is important to consider the general guidelines before actually selecting the indicators. The emphasis in this study will be on the first three desirable characteristics.

The most discussed categories of indicators are: single species, rare or endangered species and species assemblages (functional groups or guilds, and taxonomic groups). All are designed or chosen to describe and predict the impact of human interventions (disturbance) on the forest ecosystem, in order to be able to direct and guide actions in forest management (as a decision support system). Disturbance is defined as all human interventions in forests, including logging, mining, hunting and gathering.

Most indicator species discussed in the literature are quick response species. These species exhibit fast metapopulation dynamics. Stakeholders are often inclined to choose quick response species for the sake of a successful policy. Long-term monitoring systems are required in order to follow changes in slowly reacting species. These systems require a stable management to ensure that monitoring will be done for a long time on a regular basis, and this may be difficult for most developing countries.

In tropical forests, species with both slow and fast metapopulations may be considered for monitoring purposes, depending on the scope of management (long-term or short-term goals).

Single Species

Monitoring a single species in a forest is considered to be convenient, as it is cost effective and it does not take as much time and energy to study thoroughly all the aspects of this single species in comparison with assemblages of species (see, for example, Lawton *et al.*, 1998). Furthermore, changes in the population size or density are often measurable. A disadvantage is the lack of representativeness of a single species in relation to the complexity of the ecosystem. It has been suggested that keystone species may be a better indicator than a randomly chosen species.

Keystone species are species which play an important role in the ecosystem, as they have a disproportionate effect on the persistence of other species in the ecosystem structure and their integrity (see Heywood, 1995, pp. 290 for a more elaborate explanation). When such a species is removed from the system, it is expected that there will be a cascading effect on the processes and species composition of the rest of the system (Bond, 1994; Boyle and Boontawee, 1995). There has been considerable debate about the concept and reality of keystone species, but there seems to be little doubt that, in some cases, a species or species group may play a major role in the survival of the ecosystem as currently recognised. Stork (1997) argues, on the other hand, hat using keystone species for monitoring biodiversity can be disputable as their role has to be demonstrated and they are to some extent arbitrary. Strict caution should therefore be shown when selecting and using keystone species as indicators.

Threatened Species

Another category that is claimed to be useful as an indicator are threatened species (often referred to as rare and endangered). Although consisting of a single species, they are discussed separately here, as they are often used as indicator species by national and international lists of criteria and indicators. In those lists generally, no reference is made to the most recent IUCN classification of threatened species (de Iongh and Prins, 1998).

According to the World Bank (1998), species which are classified as an IUCN category under threat are not reliable indicators, because the classification may change from one year to another.

Threatened species do not necessarily represent a species group or a taxon that is typical or important for the rainforest concerned. Those species are often chosen because they are regarded as “flagship” species.

Whitmore and Sayer (1992) argue against single species indicators: “Forest managers should be cautious in examining patterns of individual species abundance. It is tempting to try to define ‘indicator species’, single animals whose presence, absence or abundance may be used in quick assessment of the status of regenerating forests. This is inadvisable because individual species generally do not respond in a consistent manner to broad environmental parameters. There are too many different factors at play at the microhabitat level”. Others also argue that, if the use of a single species does not work, it is better to use several species from one genus or family (cf. Rodríguez *et al.*, 1997; Noss, 1990). The debate still continues, as is clear from Nummelin (1998) who discusses the usefulness of single species abundance as an indicator for rainforest disturbance (see Hill and Hamer, 1998; Basset *et al.*, 1998; Watt, 1998). The implementation of measures to protect threatened species, however, can be used as a performance indicator.

Guilds

As a means of avoiding the problems of single species as indicators, the use of specific groups of species has been considered to be a good alternative. Species can be divided into different kinds of groups, the most accepted division being taxonomic and functional groups. Functional groups are considered to be the same as guilds. A “guild” is a group of species or organisms that uses the same environmental resources in a similar way (Stork, 1987; Heywood, 1995). Examples of guilds are plant species grouped according to their tolerance or intolerance of shade, or groups of animals categorised by their feeding habits: e.g. frugivores and granivores. Guilds are mostly part of the same taxonomic group and some species may show seasonal shifts in food resources. Table 2.1. gives a summary of the applicability of guilds of different taxonomic groups. It indicates that birds have the relative advantage of combining an available database with relative easy observation and vocal recognition.

The extent to which they make use of the same environmental resources implies similar roles in ecosystem processes, such as primary production or consumption. Thus the guild concept may be considered synonymous with the idea of functional groups. The use of guilds is based on three premises:

- in many situations, the guild may be the most practical taxonomic unit. Reference to a small number of guilds saves time and effort in comparison to a large number of species;
- important information on the response of forest biodiversity to the management process may be obtained at the guild level;
- key ecological roles are played by certain animal guilds, such as pollinators and seed dispensers.

We should be careful when using individual species of a guild as indicators of the abundance of the same guild, as species differ markedly between or even within habitat types, whereas overall guild abundance may not, because of species substitutions (Canterbury *et al*., 2000). If the overall abundance of a guild is used, large increases in one or two species may mask the decline or loss of others in the same guild (Mannan *et al*., 1984). Consistency of population responses among the constituent species of a guild thus determines the suitability of the guilds as indicators. Clear definitions of guilds are therefore needed.

Traditionally defined functional groups can be used (e.g., based on foraging), but functional groups based on habitat *sensu stricto* (= vegetation structure), the so-called habitat assemblages, appear particularly useful (Canterbury *et al*., 2000). The following four habitat assemblages were used by Canterbury *et al*. (2000):

disturbance sensitive species
  1. mature forest assemblage

A. disturbance tolerant species
  2. shrubland assemblage
  3. forest-edge assemblage

B. neutral species
  4. habitat generalist assemblage

Relative abundances of these assemblages have been used to form a bird community index (BCI) linking bird populations to a comparable set of four habitat assemblages in two studies (Canterbury *et al*., 2000; van Balen, 1999).

Rodríguez *et al*. (1997) provides evidence that several species of one taxon, or family (in this case, Tiger beetles), can be used to indicate site-specific, or succession-specific degeneration or regeneration of forests. He lists the following criteria for the selection of a taxon:

1. taxonomically well known and stable;
2. biology and natural history well understood;
3. populations readily surveyed, so testing is simple and cost effective;
4. higher taxonomic level: occurrence over broad geographic/habitat range;
5. lower taxonomic level: specialisation of each population;
6. evidence of patterns between indicator taxon and unrelated taxa;
7. potential economic importance.

Taxonomic and functional groups can show overlap, as the species of one taxonomic group may share the same resources. This is, in fact, logical, as these groups share the same evolutionary history. Guilds are therefore relatively good representatives of the ecosystem.

Of all the general guilds, avian guilds are often mentioned as the most practical indicator (Johns, 1997) for several reasons:

- they are easy to observe;
- they are vocally recognisable, if not seen;
- there is already an extensive database on birds, as they are a much-studied taxon.

As can be seen in Table 2.1, the relative ease of observation of birds is considered to be an advantage for possible monitoring. Mammals are often more elusive, or widely dispersed with large home ranges, or nocturnal, making regular observation difficult. Some butterfly species are restricted to the canopy and difficult to observe. In rainforests it is hard to detect animals in general. Vocal activities therefore play an important role in monitoring species. Birds, for instance, have a wide range of songs and calls, while mammals are also less appropriate for monitoring in this respect, as they have fewer vocalisations.

Mammal guilds are also useful, except that they are often harder to detect than birds (see Table 2.2). The availability of fauna databases in the rainforest is a crucial consideration in selecting indicators. An extensive background study must first be carried out before selecting indicator guilds. All available information on possible candidate indicators should be obtained, which should then be reviewed in order to select the indicator about which much has already been described, or where previous research has shown that it qualifies as a good indicator.

Table 2.1 Indication of applicability of guilds of different taxonomic groups. It is clear from this table that avian guilds have advantages over other groups

	Observability	**Vocal recognition**	**Available database**
Mammals	+/-	+/-	+
Birds	+	+	+
Butterflies	+	-	+/-
Beetles	+/-	-	-

Sources: McKinnon *et al.*, 1996 (general review of all groups in Kalimantan); Lawton *et al.*, 1998 (all categories); Johns A.G., 1996 (birds); Johns, 1997; Canaday, 1996 (birds); Prendergast, 1993 (birds and butterflies); Johns A.D., 1986 and 1987 (birds); Johns A.D. 1983 (mammals); Johns A.D., 1992 (mammals and birds); Wilson and Johns, 1982 (mammals and birds); Rodríguez *et al.*, 1997 (beetles).

TOWARDS A MONITORING PROTOCOL

The use of single species is too vulnerable to site-specific and local factors, independently of the impact of logging, for example. Similarly, the use of threatened species categories (de Iongh and Prins, 1998) is not practical. The use of guilds has clear advantages over the use of both other categories (see Table 2.2.). This approach is less vulnerable to local factors. Furthermore, guilds reflect the food production, nutrient and energy cycles of the ecosystem much better than single species.

The debate about the usefulness of certain indicator categories has been reopened by Stork (1997) and the UN Conference on “The Ecosystem Approach for Sustainable Use of Biological Diversity” held in Norway, 1999. Stork (1997) suggests that it may be possible to assess the effects of management practices on biodiversity by examining the cycles, energy fluxes, natural disease resistance and other processes, rather than the state of species or guilds. This is, however, a whole new debate, and we therefore still suggest the use of guilds as indicators is as the most practicable, until more is known about the ecosystem approach. The discussion of the ecosystem approach and its implementation for assessing biodiversity falls outside the scope of this paper.

Table 2.2 Aspects of indicators that influence applicability

	Representativeness	**Quantification**	**Monitoring**
Single species*	-	+/-	+/-
Keystone species	+/-	+/-	+
Threatened species	-	-	+/-
Guilds	+	+	+

* Randomly chosen, not keystone or endangered species.

Review of Bornean research on mammals and birds

Extensive databases already exist on the distribution and abundance of animals in disturbed and undisturbed forests in Indonesia. Reviews are presented by McKinnon *et al*. (1996) and Johns (1997). Case studies are presented about the influence of forest disturbance caused, for example, by logging, on the distribution and abundance of certain birds and mammals (see Appendix 2 for a selection of animals). This information provides a starting point for the selection of indicators.

We first discuss several avian studies, starting with Johns' (1986) study on birds and logging in Peninsular Malaysia. Johns (1986) examined the response of a species-rich avifauna to selective timber logging. He selected 13 guilds and noted the number of species of each guild present or absent in unlogged, recently logged and old logged forests. Some understory insectivorous bird guilds show special sensitivity to logging. This means a decrease shortly after logging and no restoration of species composition in old logged forest. The results show the importance of previous studies for the selection of guilds.

Johns (1996) also studied the species richness in logged and unlogged sites in Sabah. In the twenty guilds which he distinguished, overall species richness was comparable between primary and logged-over forest thanks to the presence of more forest edge species in the latter (see Appendix 3.2). He concluded that only a few species are really threatened in logged-over forest, and that most species persisted in small left over, undisturbed areas. He emphasised the importance of refuge areas in logging concessions. He also proved in this study that the understory insectivorous guild of terrestrial insectivores is extremely sensitive to logging.

Lambert (1992) analysed the consequences of selective logging for Bornean lowland forest birds and concluded that most primary forest bird species were present in areas selectively logged eight years previously. However, he identified a change in real abundance of feeding guilds, related to an overall change in the trophic structure of the understory. He observed a significant increase in the numbers of terrestrial frugivores (due to mass fruiting of *Macaranga* trees) and a similar increase in abundance of species which include nectar in their diet, associated with an increase of the flowers of plants that colonised disturbed land, such as *Mezoneuron* trees. He also observed large changes in species composition within the sallying insectivorous guilds. He finally stated that the susceptibility of logged forest to fire and our present incomplete understanding of bird behaviour and population dynamics in logged forests mean that conservationists should not be consider them as alternatives to reserves of primary forests.

It is interesting to compare the results of Lambert's paper (1992) with that of Johns (1996). These studies were actually conducted in some of the same compartments of the same logging concession, using the same techniques. The time spent on the studies was also similar, yet the results (or the interpretation) are rather different. The implication is that it can be quite difficult to draw conclusions from single studies where seasonal or longer-term fluctuations in phenology or other micro-environmental conditions can have a greater influence on study results than habitat changes caused by logging.

Wilson and Johns (1982), Johns (1987) and Johns (1997) discuss the influence of disturbance of forests on the distribution and abundance of hornbills. Hornbills are sensitive to the disappearance of specific food trees, especially figs. Figs are dependent on larger trees, which are often sought after by logging companies. Hornbills could therefore be good indicators of forests that have been logged. Hornbills have extensive home ranges, which makes monitoring difficult. On the other hand, they are easy to spot, if present. According to these studies, hornbill populations decline drastically after logging, but several species persist in heavily degraded forests (see Appendix 4). The authors give a classification of the changes in the population dynamics of most hornbill species. More studies on the ecology of hornbills would be needed in order to assess the value of hornbills as indicators.

Marsden (1998), in a study on Seram, reconfirmed independently of Johns (1986; 1996) the vulnerability of understory insectivorous birds, but also concluded that few bird species were excluded during a point count census in forest after logging. Bird species diversity (Shannon Weaver index), however, was significantly lower in logged forest.

Nagelkerke (2000) found that woodpecker species richness in plots in E. Kalimantan did not differ between primary forest and logged landscapes, but was lower in small forest fragments. Densities of woodpeckers in primary and logged landscapes did not differ significantly, although differences may become significant when more replica study sites of forest types are established. Average densities over three primary and three logged sites were lower in logged landscapes for nine out of 13 woodpeckers. Within logged landscapes, eight out of nine woodpeckers are more abundant in primary patches than in logged patches. For the Checker-throated Woodpecker *Picus mentalis* this preference for primary patches is significant. The Checker-throated Woodpecker is a highly mobile forager of the lower storeys and its density is negatively correlated with the volume of dense foliage between heights of 0 and 15 m.

Contrary to Nagelkerke, who found a decline for most species in at least one community, Johns (1996) found few differences in species composition and densities of woodpeckers between primary and logged forests in Sabah. This different finding may be due to differences in methodology. Nagelkerke (2000) used longer transects, which are more suitable for assessing densities of wide-ranging species, as a number of woodpeckers and several widely spaced out replicas of habitat types are studied instead of single plots.

Wong (1985) concluded that understory insectivorous birds in West Malaysian rain forest had not recovered 25 years after the occurrence of logging. Of the 21 species netted in primary virgin forest, only 17 were reported from logged forest, while both total numbers and number of species were consistently lower in logged forest. A point to note about Wong's results is that the logged-over forest at Pasoh was extensively treated post-logging. That is, natural regeneration was suppressed in favour of regeneration of a nearby plantation of dipterocarps. This has a great bearing on the reported differences in understory abundance of bird species.

Most mammal studies which quantify the effects of habitat disturbance, concentrate on primates. Davies and Payne (1982) give an overview of the study in which the minimum area needed for 200 adult individuals of several mammals and hornbill species to survive is estimated (see Appendix 5). This is a good indication of the possible consequences of logging, as well as of the necessary size of refuge areas. The study gives the distribution of primates in logged and unlogged areas as an indication of the sensitivity of several species to disturbances. Rijksen and Meijaard (1999) give an overview of the state of the orang-utan in Indonesia. Chivers (1980) does the same for all primates in Malaysia. Nijman (2000) studied the effects of behavioural changes, caused by habitat disturbance, on the estimated density of gibbons in East Kalimantan; and Oka *et al.* (2000) did a similar study on the behaviour of Bornean gibbons in relation to logging.

These are only examples of which primates could qualify for monitoring forest changes, as the state of the animals at the different stages of degradation is known. Johns (1992) and Johns and Marshall (1992) have done studies on the responses of vertebrates to selective logging (see Appendix 6). They show how simple analysis of ecological parameters may be used to quantify the extent to which logging affects the forest ecosystem and the extent to which it recovers over time.

Bennet and Dahaban (1995) concluded in their study in Sarawak that wildlife survival was less than reported in the study by Johns and Marshall (1995), even though extraction rates were similar. A main comment on the study of Johns was that he had used logging roads as his survey routes, which is likely to bias the results. However, in the study by Bennett and Dahaban, the abundance of many species of wildlife in the logged-over forest was affected by increased hunting made possible by increased access, not by habitat changes *per se*.

Although baseline data on the mammals of the lowland dipterocarp rain forests of Borneo are available, it is clear that it is very difficult to monitor these animals as indicators. Many species are nocturnal, are generally difficult to observe, and attributes such as longevity, mobility, large ranges, may render mammals in general as less suitable as bio-indicators. Furthermore, changes in the behaviour of mammals brought about by habitat disturbance, may lead to great differences in detectability between disturbed and undisturbed habitats. However, if properly studied, a number of selected species (diurnal primates, diurnal squirrels etc.) can be valuable as indicators for disturbance.

DISCUSSION

The use of single species is too vulnerable to site-specific and local factors, independently of the impact of logging, for example. Similarly, the use of threatened species categories (de Iongh and Prins, 1998) is not practical. The use of guilds has clear advantages over the use of the two other categories (see Table 2.3). This approach is less vulnerable to local factors. Furthermore, guilds reflect the food production, nutrient and energy cycles of the ecosystem much better than single species.

The debate about the usefulness of certain indicator categories is reopened by Stork (1997) and the UN Conference on “The Ecosystem Approach for Sustainable Use of Biological Diversity” held in Norway, 1999. Stork (1997) suggests that it may be possible to assess the effects of management practices on biodiversity by examining the cycles, energy fluxes, natural disease resistance and other processes, rather than the state of species or guilds. This is, however a whole new debate; the use of guilds as indicators is therefore still suggested as the most practicable, until more is known about the ecosystem approach. The discussion of the ecosystem approach and its implementation for assessing biodiversity falls outside the scope of this paper.

Table 2.3 Aspects of indicators that influence applicability

	Representativeness	**Quantification**	**Monitoring**
Single species*	-	+/-	+/-
Keystone species	+/-	+/-	+
Threatened species	-	-	+/-
Guilds	+	+	+

* Randomly chosen, not keystone or endangered species

Because of the many available databases and the existence of current research projects, we have considered the use of avian guilds and, particularly, understory insectivorous birds as indicators. However, further research on the applicability of avian guilds is recommended. In addition, research and inventories of mammal and other guilds should proceed, as these may prove to be good indicators when more baseline data are available.

The NWO programme for biodiversity in disturbed ecosystems is contributing to the development of indicators, as it concentrates on guilds (woodpeckers and butterflies).

The possibility of developing monitoring models on avian guilds should be examined, preferably by an ornithologist. Sufficient collaboration between botanists and zoologists would enable a useful protocol to be developed. This protocol will, if possible, cover botanical as well as fauna indicators. This mostly means linking avian guilds with succession stages in forests (Verburg, 1999; Eichhorn, 2000). The feasibility of an operational protocol that covers animals and plants together should be discussed. The advantage of an integrated protocol (botanical and zoological) is that both disciplines add information about the level of disturbance of a forest. Where data on animals are lacking, the botanical part could supply the model with the necessary data.

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MINISTRY OF FORESTRY AND ESTATE CROPS – TROPENBOS-KALIMANTAN RESEARCH: TOWARDS AN INTEGRATED CONCEPT FOR THE THIRD MILLENNIUM

Paul J.M. Hillegers

ABSTRACT

From the earliest days of the Tropenbos Foundation (1987), Indonesian and Dutch researchers were and still are devoted to the conservation, wise use and rehabilitation of the tropical rainforest. Their work is done in the framework of the International Ministry of Forestry and Estate Crops-Tropenbos Project in Sambodja, East Kalimantan. The major challenge they face is to reduce forest destruction, conserve primary forest and rehabilitate disturbed forest.
The date of this workshop, in the very last days of the 20th century, provides an excellent moment to pause and consider what has been accomplished and what will further be necessary for the sustainable management of tropical rainforest in Indonesia. Much has been achieved in the course of time, including not only pioneer achievements in the frontline of science, but also results adding to or complementing the knowledge of the Indonesian situation. Since 1995, Tropenbos has been co-operating with the NWO priority programme for " biodiversity in disturbed ecosystems". The aim of this co-operation has been to integrate biodiversity research activities and results into the overall Tropenbos programme. The objective of this article is to evaluate what the MOFEC Tropenbos Programme and the NWO Programme have contributed to sustainable forest management.

The study has been done in accordance with the ITTO set of criteria and indicators and standards of performance for sustainable forest management, which have been adopted by the Indonesian Government. The research results from 1987-1999 are grouped and discussed according to the seven ITTO criteria and indicators. Knowledge gaps and future needs have become apparent in this systematic discussion. The major fields on which to concentrate are: re-dimensioning of the sociology/culture–economy-ecology triangle; realistic and clearly defined long-term forest land use objectives; enforcement of laws and regulations; participatory management. Other areas of study include: integration of existing knowledge, techniques and experiences; the effect of fragmentation and regeneration on biodiversity; workable parameters for preserving high levels of biodiversity in forestry practices. The end of the workshop was devoted to discuss what has been achieved and what are the future needs. The outcome of these discussions was a set of recommendations which are presented at the end of this article.

INTRODUCTION

Using and managing, in the sense of manipulating tropical rainforest is as old as mankind. Before colonial powers subjected the Indonesian archipelago, local rulers were already using and protecting the teak forests on Java. The colonial Dutch East Indies Government intensified the management of the teak forests and declared them state forest land. It also included the natural wild forests on Java's volcanoes in the state forest land in order to protect the soil and water. A well-organised Forest Service was developed and a detailed set of laws and regulations was established to safeguard continuous revenues for the state and to protect the environment. After independence the Indonesian authorities retained and further developed the Forest Service. In 1967, in anticipation of the large benefits that could be derived from the natural forest on the other islands of Indonesia, the government started a concession system. Concessionaires were allowed to exploit the natural forest using a selective felling system that was well designed and regulated for its time.

In spite of the existing regulations, the natural forest resources have declined catastrophically in the last 50 years through a complex of interacting factors. Without naming a principal offender, the accelerated deforestation and loss of biodiversity can be blamed on timber exploitation, conversion to agriculture by estates and smallholders, lack of law enforcement and control, shifting cultivation and forest fires. In the first decade of the 21^{st} century the total area of primary and secondary rainforest will be further reduced, resulting in even more loss of biodiversity. Only smaller areas of conserved and protected forest will remain as primary forests. The remainder will consist only of seriously disturbed forest. The major challenge is to curb the trend of forest destruction, to conserve primary forest and to focus on disturbed forest.

The Ministry of Forestry-Tropenbos Kalimantan Project (MTKP), was started in the midst of the accelerated process of forest degradation at the end of 1987. Aware of the problems related to the declining natural forest resources and the sustainable management of the permanent forest estate, the Indonesian Government invited Netherlands' research partners to join forces with Indonesian research organisations and concessionaires. The shared objectives of the MTKP Programme were, and still are, the conservation, restoration and sustainable management of tropical rainforest. After 13 years of co-operative research efforts, the "The balance between biodiversity conservation and sustainable use of tropical rainforest" workshop offered an opportunity to present major research results. The other objectives of this workshop were to analyse the research contribution to forest policy and forest management in Indonesia and to recommend future research areas and activities.

In the period from 1988-1999 a total of 257 publications were produced, including books, PhD dissertations, MSc theses, articles and reports. These publications are listed by year in "The Publication List 1988 - 1999" (MTKP, 1999). In order to give a quantitative impression of the different subjects that have been written about, they have been grouped using the Oxford system of decimal classification for forestry. Table 1 shows the subject classification of the publications in accordance with the primary heads and certain subheads of the ODC system. The figures show that there are relatively many publications on the taxonomy and ecology of single animal and plant species and these may be arranged under biodiversity research. By far the largest group (40%) deals with the regeneration and formation of stands, especially by means of vegetative propagation. This group contributes to maintaining and restoring forest productivity. Some social aspects are assembled under the subheads “shifting cultivation” and “agroforestry”.

Table 1 Publications (books, dissertations, articles, reports, see MTKP, 1999) of the Ministry of Forestry and Estate Crops-Tropenbos Kalimantan Project in the period 1988 -1999 per subject (ODC classification).

	Subjects	Number	%
1	**Factors of the environment. Biology**	**85**	**33%**
	Site factor: soil	12	
	Zoology-animal ecology	1	
	Crocodiles	2	
	Birds	2	
	Mammals: rhino, cats, bears	4	
	Orang-utan	21	
	General botany - plant ecology	6	
	Plant morphology, physiology, carbon assimilation	3	
	Systematic botany	14	
	Mycorrhiza	15	
	Phonology, flowering	5	
2	**Silviculture**	**102**	**40%**
	Regeneration and formation of stands: general	23	
	Seed	3	
	Plant rearing, nursery practice	3	
	Vegetative propagation by cuttings	43	
	Vegetative propagation by tissue culture	5	
	Formation of stands by planting	10	
	Wildling	2	
	Direct planting of unrooted cuttings	1	
	Enrichment planting	1	
	Shifting cultivation	3	
	Agroforestry	8	
3	**Logging and transport**	**1**	**0%**
	Logging and transport; general FIEPLP	1	
4	**Forest protection**	**7**	**3%**
	Forest fires	6	
	Logging damage	1	
5	**Forest mensuration, surveying and mapping**	**28**	**11%**
	Tree enumeration trees	5	
	Surveys, site assessments, timber cruisings	4	
	Surveying and mapping. Remote sensing	15	
	Ground surveys FIEPLP	4	
6	**Forest management**	**6**	**2%**
	Forest management: general	3	
	Cost comparison	2	
	63 administration and organisation	1	
7	**Forest products. Economics of transport and processing**	**0**	
8	**Forest products and their utilisation**	**13**	**5%**
	Wood structure and properties	5	
	Minor forest products	8	
9	**Forests and forestry**	**15**	**6%**
	Forestry general accounts	11	
	Land use	4	
	Total	**257**	**100%**

The third largest (11%) group contains remote sensing, forest surveys (cruising) and growth and yield research. Resource assessment and monitoring are the key words here. The other publications are more ore less evenly distributed among the different primary heads. Ecologically related subjects, silvicultural subjects and assessment and monitoring subjects together form 84% of the total number of publications. This indicates a minor share for economic and social aspects related to sustainable management.

In order to cope with the national forestry developments in Indonesia and with global trends in forest product trade and environmental issues, Indonesia adopted the ITTO criteria and indicators (Nasendi, 1997). This system of criteria and indicators is an instrument for the measurement of sustainable management of forest (Lammerts van Bueren and Blom, 1997). In this article, the ITTO instrument is used to discuss the contribution of research results of MTKP to the sustainable management of natural tropical forest.

Seven criteria are used with their associated criteria (ITTO, 1997):
1. enabling conditions for sustained forest management
2. forest resource security
3. forest ecosystem conditions
4. soil and water
5. biological diversity
6. flow of forest produce
7. economic, social and cultural aspects

This article closes with some general conclusions derived from this evaluation and the recommendations of the workshop participants.

1. ENABLING CONDITIONS FOR SUSTAINED FOREST MANAGEMENT

Extensive legal, economic and institutional frameworks cover the use and management of forestry resources. Major legislation relevant to forestry comprises the Basic Forestry Law (Act No. 5, 1967), Basic Environmental Management Law (Act No. 4, 1982) and the Conservation of Natural Living Resources and their Ecosystems (Act No. 5, 1990) (Djakaria and Nasendi, 1997). Other laws, indirectly related to the use and management of natural resources, complement these major laws. In addition, many rules and regulations at the ministerial, directorate-general and directorate levels have been issued to arrange and control activities in the forestry sector. Forestry development is incorporated in the national development planning, which consists of 25 and 5 year cycles and annual plans (Sormin, 1999). The Ministry of Forestry, which is the administrative authority for the state's forest land, is a large organisation consisting of 5 directorates-general. The Forestry and Estate Crops Research and Development Agency is responsible for research. In 1984 the forestry research organisation, until then stationed in Bogor, was expanded and new research institutes were planned on the other major islands of the country. The new research institutes in Samarinda, East Kalimantan and in Pematang Siantar, North Sumatra were designated to specialise in natural Dipterocarpaceae forest (Marsono and Hillegers, 1995).

The MTKP project's contributions to the subjects and activities under the heading "Enabling conditions for sustained forest management" consisted of advice on policy development, institution building, training of professional foresters, assistance in establishing mechanisms and capacity for the evaluation and monitoring of forest resources and increasing public awareness.

In the course of time, the project became increasingly involved in national policy design and development. The MTKP received national authority and, the team leader served on various national committees, including those for the adjustment of the Indonesian selective felling and planting system, the formulation of sustainable forest management guidelines, the national orang-utan survival programme and the new forest inventory method. As advisor to the Minister of Forestry, the team leader contributed to various aspects of sustainable forest management through participation in national and international co-ordination and consultative groups. This involvement led to significant contributions to the formulation of new regulations for orang-utan rehabilitation and the conservation of orang-utans (Ministerial decrees of June and December 1995) and the formulation of new ministerial guidelines for cruising.

In 1984 the Forestry Institute Samarinda was established, including a number of satellite research stations throughout the different provinces of Kalimantan. The first satellite station was the current MTKP Wanariset/Sambodja research site. With the help of the project this research station was developed and institutionalised into a well known national and international site for Dipterocarpaceae forest research and orang-utan rehabilitation.

The training of government officers and concession employees as professional foresters and forestry technicians of has been a successful component of the project. PhD, MSc, structural and tailor-made programmes were provided, especially in the fields of tree identification, symbiotic mycorrhiza-tree relations, plant production (wildlings and cuttings), nursery techniques, cruising and remote sensing.

The raising of public awareness of tropical forest conservation, forest rehabilitation and sustainable use is probably the most outstanding result of the project. This has been achieved through training programmes at different levels, through visits to the Wanariset station and through many films, interviews and articles in the international and national media.

For the three decades up to 1997, Indonesia has been a success story in terms of economic growth. The role of the forest sector in this growth has been considerable. However its impact on the environment and society leaves much to be desired (World Bank, 2000). The financial crisis of 1997, the 1997/1998 forest fires, political changes in 1998 and struggles between population groups have had, and still have, adverse effects on the forests and current practices. In addition, it is feared that two recently adopted laws may increase forest degradation and the conversion of forest lands to other land uses. The new law on Decentralisation of the National Authority (Law 22/1999) gives considerable power to the provincial governments and the law on Intergovernmental Fiscal Balance (Law 25/1999) reduces the contributions of the central government to the provinces. The provincial administration will be responsible for such aspects as forest conservation and protection, forest boundary establishment, forest fire prevention and the management of protected areas. In view of these developments, the future of the natural forest resources and the role of the forests in Indonesian society is unclear. Economic, social and cultural factors determine the possibilities for sustainable management more than ecological and technical factors and warrant the need for more research in the social and economic sciences.

2. FOREST RESOURCE SECURITY

In land use statistics (CBS, 1947, BPS, 1982, DEPHUT, 1994, NFI, 1996) the Indonesian forest is classified in forest types and in forest functions. The classification of forest types refers to the original vegetation characteristics; the forest types are mangrove forest, swamp forest, coastal forest, rainforest, deciduous forest and secondary/idle forest. The functional classification refers to the land (forest) use objectives, which are conservation forest, protection forest, limited production forest, production forest and conversion forest. With some refinements these classifications did not change that much in the course of time. Remarkable is that the refinements for the forest types are based on site characteristics within the main forest types, mainly on soil and hydrology attributes. While going through the statistical yearbooks another noticeable feature is that the area of permanent forest land does not change that much during the years (about 112 million ha), in contrary with forest land with a conservation function. The area of nature conservation forest increased from about 8 million ha in 1979 to 19 million ha in 1993.

Detailed statistical information is provided by the Final Forest Resources Statistics report of the National Forest Inventory project (NFI, 1996). In the context of the deforestation development as given here, two data sets are important to mention. The first shows that the area with the function production forest will all be logged or otherwise disturbed in the first decade of the 2000 millennium. The second set shows the species richness using vernacular names and the biodiversity as indicated by the Shannon-Wiener index. Looking at the maps the first impression is that the loss of biodiversity may be not that severe. Travelling through the country one gets another impression, especially after the huge wildfires in 1997/1998.

The current description of the forest resource base needs a thorough review. Forest types should not only be based on the original natural vegetation types but should reflect also the current characteristics, that is several stages of degradation/regeneration. The same counts for the functional classification. The criteria for the classification, developed more than 20 years ago, may need a critical re-examination. Certainly the delineation of the different functional forest use classes are not all very realistic any more. Changes in flora and fauna, current land use and future development plans need other outlines on maps.

Past and present MOF-Tropenbos Kalimantan research provides ample elements to contribute to Forest Resource Security. An early result of the MTKP project is the publication "Detailed soil survey and physical land evaluation in a tropical rainforest" (Bremen et al., 1990). For an up to date detailed inventory of the vegetation on official forest land and the demarcation of the different functional forest classes as well as for monitoring changes, natural and/or man-made, remote sensing is indispensable. The advanced radar based remote sensing monitoring system for forest management and land cover change in Indonesia (Hoekman, 1995, Hoekman, these proceedings; Prakoso et al., these proceedings) has great potentials to be the new system for the Ministry of Forestry. Ground surveys to complement the remote sensing data can be based on taxonomic and ecological work on trees and animals. Major results here are publications on trees and seedlings in natural forest and in secondary forest and on animal ecology of birds and mammals (see discussion under Biodiversity). For monitoring changes knowledge on forest degeneration and regeneration processes is a prerequisite. Recently, work on modelling secondary forest succession in tropical rainforest (Verburg, these proceedings), on tree diversity in secondary forest and on regeneration of pioneer species after fire (Eichhorn, these proceedings) has started.

3. FOREST ECOSYSTEM CONDITIONS

Indicators under this criterion are concerned with the quality of the forest and include disturbance and stress and climatic effects. Ineffective and destructive logging practices and stress caused by extreme dry periods followed by fire outbreaks are the main threats to sustainable forest management in Indonesia. The impact of logging, water stress and forest fires became research subjects of the MOF-Tropenbos Kalimantan project.

The project on reduced impact logging and ground survey forest inventory in combination with radar, GPS and GIS was started in 1994. It was designed as a broad integrated study to serve as a starting point for a software program called Forest Inventory End Product Linking Programme FIEPLP (Smits, 1998). A ground survey technique was developed that produces accurate tree position maps combined with guidelines for felling direction and skid-road design to reduce felling damage and soil erosion. It is also a useful instrument for delineating harvest compartment boundaries along ecological lines. This new harvest area unit replaces the previously used rectangular blocks. The cruising system was adopted by the Ministry of Forestry and became a guideline for the Indonesian Selective Felling and Planting System (TPTI). The survey system is complementary to the radar-based remote sensing monitoring system (see Forest Resource Security and Flow of Forest Produce).

In 1997/1998 very disastrous forest fires struck major parts of South East Asia, in particular, the Indonesian archipelago. The El Niño phenomenon caused an extreme drought and fierce forest fires persisted for several months in May-June 1997 and in the first months of 1998. Earlier profound El Niño effects, which occurred in 1982/1983 and in 1991/1992, also brought unusually dry periods with damaging water stress and extensive forest fires (Noor and Leppe, 1995). These dry spells are most probably related to climatic changes, and it is feared that they will occur more frequently in the future. In combination with already burned vegetation with a higher combustibility, fires will become an increasing threat to tropical rainforests.

South and East Kalimantan, in particular, suffered from the 1997/1998 fires, which had a very serious effect on the ongoing research of the MOF-Tropenbos Kalimantan project. All of the experimental sample plots in the Wanariset Sambodja Research Forest were burned down and the nearby Sungai Wain Protection Forest, which was the location of various ecological studies, was seriously damaged (Effendi et al., these proceedings). Research programmes started before the forest fires had to be adapted to the new situation (Eichhorn, these proceedings; Fredriksson and de Kam, 1999), while other researchers started new projects to study the effects of fire (Effendi et al., 1999; Iriansyah et al., 1999; Priadjati, 1999). Forest fire management (comprising fire prevention, early warning systems, fire fighting and post-fire relief), the effects of fire on flora and fauna and forest restoration have already been declared as research priorities.

4. SOIL AND WATER

This criterion is concerned with the regulatory function of the forest, especially in relation to off-site values. The hydrological regulatory function and the soil protection function of the forest are well understood in Indonesia. The wild forests on the steep volcanic slopes in Java were already given protection status at the beginning of this century. The slope gradient and height above sea level are the major criteria for the functional classification of forest land in protected forest. Under the former Indonesian Selective Felling Systems (TPI) regulations and obligatory guidelines to reduce logging impacts on the forest environment and on the lower parts of watersheds with other forms of land use were set. Felling intensity restrictions and prohibiting felling in buffer strips along waterways should safeguard the hydrological sponge function and reduce the sediment load in rivers. Soil losses are prevented by proper truck road alignment and construction, small landings sited on flat areas , skid road layout and density etc.

The current Indonesian Selective Felling and Planting System (TPTI) is well designed and regulated. Environmental logging damage can be further reduced and logging efficiency increased by providing guidelines for cruising by means of GPS-assisted tree mapping, tree enumeration and terrain features incorporated in a geographic information system and combined with radar remote sensing techniques (see FIEPLP under Forest Ecosystems Conditions).

The existing system of rules, regulations and guidelines may still not prevent all adverse logging impacts but, if it is properly adhered to, the system can reduce environmental damage considerably. The political and self-centred economic interests of the stakeholders involved, the government’s shortcomings in monitoring and law enforcement and the top-down approach without full participation of the stakeholders, especially the local population, are the main reasons behind the poor state of forest land in many parts of the country. Research into social, cultural and economic aspects may provide better instruments or standards of performance for sustainable forest management.

5. BIOLOGICAL DIVERSITY

According to the ITTO (1997), the Biological Diversity criterion should include three national measures:

- a politically and ecologically viable system of protected areas containing representative samples of all (original) forest types in the country;
- effective protection of species, especially those that are endangered, rare or threatened;
- conservation, at an appropriate level, of the biological diversity in those forests managed preliminary for production.

The CBD defines biological diversity as diversity at the ecosystem, species and genetic levels. Biological indicators can be used in monitoring and evaluation procedures. The MTKP project research has contributed to the three national measures and to the further development of standards of performance for the criteria.

The building of a systematic network of protected areas all over the archipelago was given momentum in the late 1970s and early eighties when the Directorate of Forest Conservation of the Directorate General of Forestry received assistance from the UNDP/FAO. The National Park Development Project drew up a National Conservation Plan for Indonesia (MacKinnon, 1982, 7 volumes) which was the base for the current protected area network. Work on conservation retained its momentum in the decade following these major conservation efforts. In the period from 1979 to 1993 the area of nature conservation forest increased from about 8 million ha to 19 million ha. The policy is to increase the total protected area to 20 million ha, a coverage of 10% of the total land area. In 1993. the National Planning Agency of the Ministry of National Development Planning published a Biodiversity Action Plan for Indonesia (NDPA, 1993). This plan was an example of the government's positive attitude towards conservation. At the same time, it revealed the gaps in the protected area network, the need for more basic knowledge of ecosystems and species, the lack of databases, the need for assessment and monitoring systems and the absence of an effective management organisation.

The contribution of the MTKP Project consisted of several countrywide surveys of crocodiles (Meijaard and Sozer, 1997; Meijaard, 1997), Malayan bear (Meijaard, 1997), Bay cat (Meijaard, 1997), and orang-utan (Meijaard, 1997). The standard work "Our vanishing relative. The status of wild orang-utans at the close of the twentieth century" from Rijksen and Meijaard (1999) can especially help in the selection of new protected areas for larger wildlife species. Other research underlined the need to upgrade the protected status of areas for orang-utan rehabilitation (Susilo, 1995) and to conserve biodiversity in periurban areas (Fredriksson and de Kam, 1999).

The species diversity in Indonesia is one of the richest in the world. At present, only the majority of the larger animal species have been well described. Many higher plant species still need taxonomic classification, while many smaller faunal and floral organisms still need to be included in scientific records. The taxonomic work on the tree species and seedlings of undisturbed and secondary forest in the Balikpapan Samarinda area and the Wanariset Herbarium received international recognition. This systematic botanical research was one of the pillars of the MTKP Project research and the establishment of the Wanariset Herbarium is a major contribution to the institutionalisation of the forestry research organisation in Indonesia. Major publications in this area are from Kessler and Sidiyasa (1994, 1995), Sidiyasa (1998), Sidiyasa et al.(1999), Bodegom et al., (1999) Some research on wood properties has added to the knowledge of some important tree species (Bosman, 1997). In his PhD thesis Dipterocarpaceae: mycorrhiza and regeneration, Smits (1994) gives records of fungi species important for the symbiotic relations between fungi and trees.

The NWO priority programme on "biodiversity in disturbed ecosystems" has focussed on biological indicators, as described in the articles in Chapters 15 - 22 of these proceedings.

The rehabilitation project for orang-utans received the most national and international attention for single species conservation. It started as a private initiative of the MTKP project team leader, Willie Smits, to take care of abandoned and confiscated orang-utans. The project developed into a large and unique reception and quarantine centre, in which captive orang-utans are checked for diseases, habituated to living in groups again and prepared for release into the wild (Warren, 1996; Russon, 1996).

Genetic diversity plays a prominent part in the vegetative production of tree seedlings to be used for enrichment planting or for plantations to rehabilitate *Imperata cylindrica* grasslands. This research field will be discussed under the next heading, the Flow of Forest Produce.

The importance of assessment and monitoring applies to all the criteria and is indispensable for the evaluation of the standards of performance. The combined remote sensing and ground survey method must be mentioned again. Another recent research field is the use of fauna indicators for monitoring the impact of disturbances in forest structure and in biodiversity, using biological indicators. Van der Hoeven and De Iongh give a review in these proceedings.

6. FLOW OF FOREST PRODUCE

This criterion is concerned with the production of wood and of non-wood products. ITTO (1997) includes resource assessment, planning procedures, management directions and monitoring and evaluation procedures as indicators under this criterion. Most of the research of the MTKP Project was directed towards supporting this criterion. The research includes growth and yield research, mycorrhiza - tree relations, seedling production, stand establishment and non-timber forest products.

There is a choice between two management systems for sustaining the productivity of virgin and logged-over forest and restoring the productivity of degraded forest land. Selective felling based on natural regeneration that may be complemented by enrichment planting is the first option. The second is plantation forestry. Other systems, not practised on a large scale, are mixtures: clear cutting with regeneration or clear cutting with plantation. The first system is by far the most system practised. In Indonesia a special selective felling system was developed in the 1960s, known under the name “Indonesian Selective Felling System” (TPI). A major change occurred in 1989 with the obligation to implement enrichment planting on sites where the vegetation had been removed or where the density of commercial future trees was to low. This system, the Indonesian Selective Felling and Planting System (TPTI), is currently practised, after undergoing a minor revision in 1993.

The estimated log consumption in 1996 was 44.57 million m^3 and the official estimates for log supply for 1996/97 was 26 million m^3. The estimate of sustainable production in 1995 was 22 million m^3. As against this, the wood processing industry had a processing capacity of 53.4 million m^3 in 1996. The mismatch between log production, and especially sustainable production, and processing capacity points to two major problems. These are poor commercial logging practices and the extent of illegal logging (Marsono and Hillegers, 1995; World Bank, 2000).

A major effort in the beginning of the MTKP Project was the rehabilitation of Growth and Yield plots in the ITCI concession established in 1972-1976. Detailed tree location maps, taxonomic identification, tree enumeration and soil studies were made. The plots are unique because of the long period of detailed measurements. The principal researchers connected with this study were van Eijk-Bos, Iriansiyah, Leppe, van Bremen, Oldeman, de Kock and Suryokusumo; for references see MTKP Publication List 1988-1999. De Kock and Suryokusumo give a review of this research in these proceedings.

On the basis of the work of van Eijk-Bos "Tree species composition and increment of dipterocarp Forest in permanent plots in East Kalimantan" (1997) and of other growth and yield studies, de Kock (1999) reaches some remarkable conclusions in his article "Yield Regulations for KPHP": "Sustained timber harvests from natural forests are seldom justifiable on financial grounds, but it is widely believed that they can help pay for maintaining invaluable ecosystems and social structures." and "The TPTI rules are found to be suitable for first time logging in virgin forest as they result in a somewhat heavier-stocked residual stand than what is recommended here and thus lead to a more gradual transition to the regulated state."

Allowable harvesting of timber or the use of other benefits of the forest without the sacrifice of its ecological potential, in other words, sustainable forest management, is under continuous scientific discussion in the International Tropenbos Foundation community. In a draft article, "Some key elements for the design of a sustainable forestry system", Lammerts van Bueren (1999, not published) introduces the Ecologically Allowable Harvest (EAH) m^3/ha as a new parameter for regulating the use of forest products, in particular, timber. The EAH m^3/ha is the actual harvest volume per single hectare resulting from the merchantable harvest volume/ha on that specific hectare and the application of ecologically based guidelines to ensure sustainability. Introducing this new parameter may help to develop standards of performance for particular forest functions or benefits through quantifiable threshold values and the extraction of forest products, timber or non-timber, in m^3/ha, kg/ha or in other measurable quantities.

The sustainable extraction of non-timber forest products (NTFP) is feasible only if watershed protection, erosion control, biodiversity conservation and other environmental services are given a financial value is the conclusion of the PhD research of van Valkenburg (1997). In his article "Non-timber forest products in a changing environment" (these proceedings), the effects of disturbance on species composition and economic potential are discussed. Special attention is paid to rattan resources, present-day land use systems and management options.

Most of the MTKP research has been directed towards the supply of good planting stock for Dipterocarpaceae species. Dipterocarp trees flower irregularly, often at intervals of several years. Most of the seeds cannot be stored longer then a few weeks. The irregular availability of planting stock was an important factor limiting the use of dipterocarps in enrichment plantings and in plantations. Another reason for not using dipterocarps was unfamiliarity with the role of ectomycorrhizae in the growth of seedlings and trees. Four main research lines were followed:
1. mycorrhiza - plant relations
2. production of seedlings
3. enrichment plantings in logged-over and burned forest
4. reforestation of *Imperata cylindrica* grasslands

The first mycorrhiza research consisted of a study of the different ectomycorrhizal fungi, their relationship with specific dipterocarp species and the physical factors determining the presence and growth of the fungi. Inoculation experiments tested the growth performance of seedlings with and without mycorrhiza. The results were published in a PhD thesis "Dipterocarpaceae: Mycorrhiza and Regeneration" (Smits, 1994). Another study of the tree-mycorrhiza seedling connection started slightly later. It included a study of the natural regeneration of Dipterocarpaceae, planting experiments in greenhouse and in natural forest, eco-physiological measurements of photosynthesis and sugar transport. An important finding was that young seedlings depend on sugars from the mother tree, transported through the ectomycorrhizal connections. Yasman (1995) presented these findings when he defended his PhD thesis at Wageningen Agricultural University. A follow-up of this mycorrhiza research is the ongoing PhD study of Mulyana Omon. The subject of his study is the development of mycorrhizae and their species succession on vegetatively propagated *Shorea leprosula.* Factors such as physiological ageing, environmental stress factors (e.g. light and nutrients) and the presence/availability of suitable fungi influence the succession of ectomycorrhizal fungi.

Greater insight into mycorrhizal-seedling/tree relations was the basis of the seedling production. In the nursery of the Wanariset station, propagation techniques were developed for planting stock from seeds, from wildlings and from cuttings (Tolkamp, 1996). The straightforwardness, effectiveness and product quality of the techniques resulted in their fast adoption by the concessionaires and by the Ministry of Forestry. In "Vegetative propagation to assure a continuous supply of plant material for forest rehabilitation", Priadjati (in these proceedings) provides a review of the propagation work.

The TPTI prescribes enrichment planting after selective felling and the restoration of damaged sites after log extraction operations. Millions of hectares of burned forest areas require rehabilitation. The MTKP started experiments with line plantings in 1988. Different dipterocarp planting stocks were tested, as well as planting in lines and between lines. Species were selected in elimination trials (Leppe and Smits, 1996). Unfortunately, the great forest fires of 1997/1998 burned all the 13 experiments that had been established in the ten-year period from 1988-1997. New experiments have now been started. Effendi et al. (these proceedings) reviews the line planting research.

Millions of hectares of *Imperata cylindrica* (alang-alang) grasslands, the result of repeated burning, need to be rehabilitated in Indonesia. The MTKP has developed a ecologically-based strategy to accelerate reforestation with dipterocarp species and to create a mixed dipterocarp-dominated forest where natural regeneration will sustain the forest. Tolkamp et al. (these proceedings) summarises the first results of the study, which include the selection of pioneer and dipterocarp species, the effects of fertiliser application on succession and the domestication of promising species.

7. ECONOMIC, SOCIAL AND CULTURAL ASPECTS

This criterion assumes that "a well managed forest is a constantly self-renewing resource which, if economically viable, will produce a range of social, cultural and economic effects, making an important contribution to the sustainable development of the country". The criterion comprises four indicators: economic effects, social effects, cultural effects and community participation. The MTKP research has been related to all of these indicators, except for cultural effects.

The overall research strategy of MTKP was directed towards the development of an integrated management system for forest resources based on the sustainability principle. A long-term development objective was the creation of a management information system which could facilitate policy development and implementation (Smits, 1998). The management information system should consist of a central nucleus programme with several modules feeding ecological, forestry, and economic and social data into the central nucleus. A start was made with the creation of the Nursery Model, a software package that calculated the costs of nursery operations to produce dipterocarp planting stock. Another module was the growth and yield database. Further development resulted in the Cost Comparison Model (Hinssen, 1995), a model in which different silvicultural systems can be designed and tested for their profitability. Other planned modules of the overall management system include FIEPLP and the radar-based remote sensing monitoring system (see Forest Ecosystem Condition). An additional species-site-matching package enables tree species to be selected for the desired silvicultural system. However, the total system has so far only reached the stage of a very early test model. Only the Cost Comparison Model has been well described so far, but has not yet been developed into a user-friendly package for large-scale use. The remote sensing monitoring system has the best prospects for international recognition and large-scale use (see the articles of Hoekman and Prakoso et al, in these proceedings).

MTKP research on sugar palm cultivation started in 1987 with the objective of involving local communities in the management of the forests around the Wanariset research station. The research has mostly focussed on solving practical problems such as optimal germination, seed age, storage, seed size and provenance. Differences in productivity between provenances, age of fruiting, harvesting techniques and social aspects of planting sugar palms have also been studied. Apart from technological improvements, the results also show that former shifting cultivators are capable of increasing their income through the planting of sugar palm and harvesting its products. Owing a sugar palm plantation had a positive effect upon the life style of communities. They were less prone to use fire. Other MTKP research in this field include social surveys among migrant pepper farmers in East Kalimantan (Boer, 1993)

‘Conversion of *Imperata cylindrica* grassland into an agroforestry system by application of mycorrhiza and shading trees’ is the title of the PhD study by Murniati (these proceedings). The research is concerned with persuading transmigrants and older local communities to participate in efforts to change their agricultural practices into more productive forms of land use and to increase their income.

CONCLUSIONS AND RECOMMENDATIONS

The overall conclusion of the above review of the state of the art of sustainable management in Indonesia is that ecological and technical knowledge is not the limiting factor for sustainable forest management. If they are adhered to and until new management approaches become available, environmental and natural resource legislation and rules and regulations for forest protection and use form a sufficient basis for wise use of forest resources in the medium term. Political, economic, social and cultural factors are the factors that determine the current poor situation of forest resources and the forest sector as a whole. A dimensioning of the axes of the ecology/technology-sociology/culture–economy triangle is necessary towards the economic and social people-oriented axis.

The predictions are that, by 2010, all the currently designated production forest will have been logged. Major parts of the production forest will consist of heavily disturbed logged-over forest, burned forest and *Imperata cylindrica* grasslands. New, realistic policies for these forestlands need to be developed, based on realistic forest resource information. The latter calls for a fast, efficient and accurate assessment and monitoring system. The MTKP project should continue to give this research priority.

Forest wild fires become an increasing threat to sustainable forest management. Climatic changes are causing extended dry periods with high fire risk. This risk, combined with vegetation types that are becoming increasingly combustible, is already a real threat, as has been shown by the catastrophic fires of 1997/1998. Research on forest fire management must be a research priority in the coming project phase.

Biodiversity degradation is a serious danger in Indonesia, in spite of 10% of the land being covered by conservation areas. Many conservation areas have been seriously damaged by the exploitation of natural resources (oil, gold, coal, other minerals, logging), agricultural encroachment and illegal hunting. Fragmentation of the landscape adds to further degradation of biodiversity. Research should provide easily assessable standards of performance to preserve high levels of biodiversity in forestry practices and wise use of natural resources.

The political and self-centred economic interests of the stakeholders involved, the government's shortcomings in monitoring and law enforcement and the top-down approach without full participation of the stakeholders, especially the local population, are the main reasons behind the poor state of forest land in many parts of the country. Research into social, cultural and economic aspects may provide better instruments and standards of performance for sustainable forest management. This research should include the study of mechanisms that lead to the acceptance and enforcement of laws and regulations. Participatory management and Integrated Conservation and Development Project (ICDP) approaches may be useful instruments to explore.

The results of the overall MTKP research strategy to assist in creating an integrated management decision system consisting of advanced software which combines social, cultural and economical factors, remote sensing, field surveys and ecological/biodiversity modules has been partially successful. The need for such a system is widely recognised. Other organisations are also aiming at the development of similar systems. It is recommended that forces should be combined to continue in the development of instruments for integrated sustainable management.

At the end of the workshop, the participants discussed in three separate sessions the research results so far achieved and formulated recommendations for future actions and research priorities. In the closing plenary session the general meeting adopted the following recommendations:

- Complete ongoing projects with a view to the proper dissemination of relevant results and build on existing research;
- The strength of the Tropenbos programme is on conservation, reduced impact logging and the rehabilitation of degraded lands (pioneer species);
- It is important that socio-economic research is included in the short term. What are stakeholders doing and why?
- Rehabilitation of degraded areas with community participation;
- Educate the people to show them the importance of biodiversity for their well-being and for the future;
- Fundamental biological research is needed to analyse the effects of stakeholder activities on the forest ecosystem;
- More research is needed on the potential of local tree species for enrichment planting and plantations;
- Make fundamental research on biodiversity indicators operational;
- Monitor the effects of silvicultural measures and rehabilitation on biodiversity;
- Improve the scientific output and profile of the programme by publication in international journals;
- Focus research on applicability at the concession level;
- Evaluate different land use systems for their contribution to biodiversity;
- Scientific underpinning of sustainable forest management;
- Focus research on Sungai Wain;
- Improve cooperation with other programmes.

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COMPOST MADE OF FOREST DEBRIS: ITS QUALITY AND PROSPECTS AS A SEEDLING MEDIUM

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ABSTRACT

Sustainable forest management involves various silvicultural techniques, such as continuous seedling availability and fertiliser application. Fertiliser is used to increase soil productivity and assist the growth of seedlings. Fertiliser demand is increasing, but its application is expensive. The waste from forest industries and forest debris is increasing but it has so far been little used. This waste can be converted into compost. The present study was carried out to study the effectiveness of compost made of forest debris, sawdust and sludge from a pulp factory as a seedling medium.

The forest debris was treated for 4 to 6 weeks, after which the material was ready for use. This condition was indicated by the C/N ratio (around 20 to 26), stable temperature and normal acidity (around 5 to 6). The pH of the material during treatment increased from less than 3.5 at the start to 5.0 after composting was achieved. Compost made of sludge did not reach a C/N ratio below 20 during the treatment.

Compost may be used as a fertiliser, but also as a growth medium for seedlings. The growth medium obtained from *Shorea* spp. leaf litter gave the best results. The average height of seedlings grown on soil: unchopped *Shorea* spp. compost 1:1 and 1:2 was 19.84 ± 2.52 cm and 21.04 ± 2.27 cm, respectively. The quality index of the seedlings grown on the two media was 0.18 ± 0.03 and 0.14 ± 0.01, respectively. Soil as a control gave the best quality index for seedling growth. This indicated that the higher the C/N ratio of the compost, the more difficult it is for the nutrient to be absorbed by the plant.

Keywords: seedling, compost, EM-4, forest debris, *Shorea selanica*

INTRODUCTION

Sustainable forest management involves various silvicultural techniques, such as continuous seedling availability and fertiliser application. Fertiliser is used to increase soil productivity and growth of seedlings. In relation to this, fertiliser demand is increasing but its application is expensive. Waste from forest industries and forest debris is increasing but hitherto unused, whereas it can be converted into compost.

Continuous seedling availability needs not only good seed from a good provenance, but also a medium for propagating and growing plants. Topsoil is commonly used as a propagating medium, but using topsoil as a seedling and propagating medium in large plantations is not recommended. The latter need bulk soil that may degrade land, because the soil is carried from the forest to nursery. Meanwhile, compost may be used as seedling and propagating medium. Mixed with soil, compost adds organic matter (Hartman and Kester, 1983).

Composting can be defined as the biological decomposition of bulk organic wastes under controlled conditions (Hartmann and Kester, 1983; Polprasert, 1989). Naturally, some microorganisms, such as bacteria, fungi and actinomycetes, work as a decomposer. In a controlled aerobic process, composting was carried out by successive microbial populations combining both mesophilic and thermophilic activities (Polpraset, 1989). Effective microorganisms-4 (EM-4) is a trade name for a fermenting solution of mixed microorganisms, consisting of *Lactobacillus* spp., yeast, photosynthetic bacteria and Actinomycetes. The microorganisms work as decomposer, blocking soil pathogens and increasing the activity of indigenous non-pathogenic microorganisms (Higa and Parr, 1994).

The objective of the study was to investigate the differential response of seedling growth to compost as a planting medium and to the composition of the medium.

MATERIALS AND METHODS

Seeds of *S. selanica* were collected from Haur Bentes Experimental Garden, Jasinga, Bogor. They were sown on a sterilised silt in a greenhouse for four weeks. The study was carried out in a greenhouse of the Forest and Nature Conservation Research and Development Center (FNCRDC) Bogor, Indonesia.

Some forest debris has been composted in aerobic conditions using EM-4, as described by Mindawati *et al*. (1998). The materials were treated for 6 weeks, and each week the temperature of the material, pH, humidity and C/N ratio were measured.

Seedlings were planted in mixed soil with some compost made of forest debris and soil as a control. The soil used in this experiment was a red-yellow podzol collected from a 0-20 cm depth under a Dipterocarpaceae stand at Jasinga, Bogor. Plants were harvested eleven months after transplanting (MAT), the shoot and roots were dried at 70 ^{o}C and weighed. The quality index of the seedling was calculated using Dickson's equation (1960, cited by Bickelhaupt, 1980).

This experiment used a randomised factorial design with two factors, i.e.:

1. Composition of mixed soil and compost, consists of two levels; 1:1 (S1) and 1:2 (S2)
2. Kind of compost consists of 5 levels;
   - Unchopped Litter of Shorea spp. (K1)
   - Mixed Litter of Shorea spp. + sawdust (K2)
   - Chopped Litter of Shorea spp. (K3)
   - Sawdust (K4)
   - Sludge from a pulp factory (K5)

Each treatment was replicated twice. The parameter measured was the growth of seedling height and stem diameter. Analysis of variance was performed in all combinations in a factorial design.

RESULTS AND DISCUSSION

Status nutrient of the compost

The forest debris was treated during 4 to 6 weeks, after which the material was ready to use. This condition was indicated by C/N ratio (around 20 to 26), stable temperature and normal acidity (around 5 to 6). The pH of the material which was obtained from sludge, increased during treatment from less than 3.5 at the start to 5.0 after composting was achieved (Mindawati *et al*., 1998).

The quality of the compost is indicated by its nutrient status, particularly the macronutrient content. Compost made of sludge has relatively the highest nutrient content. The nutrient content of some compost made of forest debris is represented in Table 1. Based on Perhutani's standardisation (1997), good compost has a C/N ratio below 20. Compost may be used as an organic fertiliser or planting medium, because compost adds organic matter to soil, which increasing the soil nutrient content, improving soil texture and feeding indigenous soil microorganisms.

Table 1 Nutrient content of some compost made of forest debris (Mindawati *et al*, 1998)

Kinds of Compost	**Nutrient content (%)**					**C/N Ratio**
	N	P	K	Ca	Mg	
Unchopped Litter of Shorea spp.	1.53	0.24	0.22	0.23	0.24	20.60
Litter of Shorea spp. + sawdust	1.57	0.24	0.24	0.25	0.21	21.30
Chopped Litter of Shorea spp.	1.42	0.23	0.24	0.30	0.21	21.40
Sawdust	1.40	0.21	0.19	0.24	0.19	21.50
Sludge from a pulp factory	1.51	0.28	0.24	0.32	0.30	24.70

Height and Diameter Growth

Height growths of S. selanica seedlings were not affected by different planting media. The best height of *S. selanica* (21.04 ± 2.27 cm) was obtained from mixed soil and unchopped litter of *Shorea* spp. (1:2). Whereas the height of seedlings which were grown on mixed soil and sludge compost (1:1) varies widely, as indicated by the high standard deviation (Table 2).

Table 2 The effect of interaction between compost and composition of medium on the height and diameter growth of *S. selanica* seedlings at 11 months after transplanting (MAT).

No.	**Treatments**	**Height (cm)**	**Diameter (mm)**
1	Soil : litter compost (1:1)	19.84 ± 2.52a	3.39 ± 0.21b
2	Soil : litter + sawdust compost (1:1)	15.30 ± 1.89a	2.94 ± 0.36b
3	Soil : chopped litter compost (1:1)	17.19 ± 2.63a	4.91 ± 1.95a
4	Soil : sawdust compost (1:1)	15.00 ± 1.98a	3.06 ± 0.06b
5	Soil : sludge compost (1:1)	24.22 ± 18.29a	3.14 ± 0.53b
6	Soil: litter compost (1:2)	21.04 ± 2.27a	3.45 ± 0.17b
7	Soil: litter + sawdust compost (1:2)	16.39 ± 1.58a	3.09 ± 0.03b
8	Soil: chopped litter compost (1:2)	15.65 ± 1.47a	3.20 ± 0.01b
9	Soil: sawdust compost (1:2)	15.11 ± 2.74a	3.20 ± 0.19b
10	Soil: sludge compost (1:2)	13.97 ± 0.19a	3.03 ± 0.12b
11	Soil (control)	16.22 ± 1.52a	3.19 ± 0.10b

Means followed by the same letter in the column are not significantly different by DMRT at the 5% level

S. selanica which was grown on mixed soil and litter of *Shorea* spp. sawdust compost (1:1) had the biggest stem diameter growth, while mixed soil and sludge compost had the smallest stem diameter. Seedlings which were grown on sludge compost tended to have slow growth, although the nutrient content of the sludge was sufficient. It may have been due to its C/N ratio (> 20), which indicated the maturity of the compost. The lower the C/N ratio, the more mature the compost.

Shoot-to-root ratio

The different interaction of composition medium and kinds of compost (Table 3) affected the shoot-to-root ratios of S. selanica seedlings. The ratio was based on the dry weight of the seedling. The total dry weight of a plant represents the net gain in photosynthate. Shoot-to-root ratio reflects a concern for the balance of the seedling (Bickehaupt, 1980).

Table 3 shows the shoot-to-root ratio of *S. selanica* seedlings on different planting media. Litter compost as a seedling medium tended to increase the growth of seedlings, while sludge compost tended to cause slow growth, especially at a of soil: compost composition of 1:2. The sludge compost should be decomposed for longer than 6 weeks until it is mature.

Table 3 Shoot and root ratio of *S. selanica* seedlings at the age of 11 MAT on different planting media

No.	Treatments	Shoot dry wt	Root dry wt	Shoot: root
		----------------gram------------		
1	Soil: litter compost (1:1)	1.649 ± 0.278	0.314 ± 0.063	5.27 ± 0.16abc
2	Soil: litter + sawdust compost (1:1)	1.200 ± 0.578	0.187 ± 0.074	6.30 ± 0.59ab
3	Soil: chopped litter compost (1:1)	1.253 ± 0.650	0.263 ± 0.111	4.66 ± 0.51abc
4	Soil: sawdust compost (1:1)	1.277 ± 0.011	0.233 ± 0.016	5.49 ± 0.44abc
5	Soil: sludge compost (1:1)	0.972 ± 0.955	0.242 ± 0.076	3.58 ± 2.83c
6	Soil: litter compost (1:2)	1.548 ± 0.040	0.248 ± 0.013	6.24 ± 0.17ab
7	Soil: litter + sawdust compost (1:2)	1.098 ± 0.108	0.174 ± 0.012	6.93 ± 0.13a
8	Soil: chopped litter compost (1:2)	1.123 ± 0.131	0.275 ± 0.036	4.10 ± 0.05bc
9	Soil: sawdust compost (1:2)	0.996 ± 0.120	0.154 ± 0.057	6.82 ± 1.77a
10	Soil: sludge compost (1:2)	1.002 ± 0.499	0.220 ± 0.087	4.44 ± 0.50abc
11	Soil (control)	2.091 ± 0.108	0.336 ± 0.003	6.22 ± 0.27ab

Means followed by the same letter in the column are not significantly different by DMRT at the 5% level

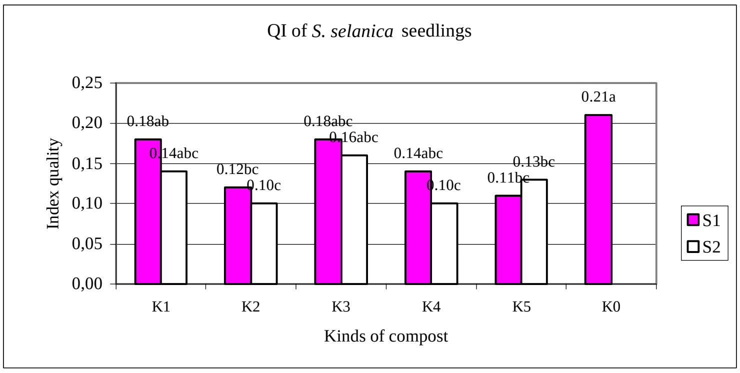

Figure 1 Quality index of *S. selanica* seedlings at the age 11 MAT on different planting media. K indicates compost of forest debris (0, control; 1, unchopped litter of *Shorea* spp.; 2, litter of *Shorea* spp. + sawdust; 3, sawdust; 4, chopped litter of *Shorea* spp.; 5, sludge). S indicates soil and compost composition (1, 1:1; 2, 1:2). Means followed by the same letter in the column are not significantly different by DMRT at the 5% level.

Quality index

The quality index (QI) has been correlated with the soil nutrient status and has been used to revise the fertiliser recommendation (Bickelhaupt, 1980).The quality index of *S. selanica* seedlings, which were grown on different seedling media, is shown in Figure 1.

The best quality index is shown by the control (soil). This reflected the fact that compost treatment in this experiment did not increase soil nutrient content. Mixed compost with soil added organic matter. This was related to the characteristics of the compost. The more mature the compost, the more easily its nutrients are absorbed by seedlings. Composts made of forest debris in this experiment were not sufficiently decomposed. Even though the nutrient content of the compost is sufficient, its nutrient may not be absorbed by the seedling. The organic matter which is added to the soil may improve the soil texture.

CONCLUSION

Compost made of forest debris has a sufficient nutrient status. It tends to increase soil organic matter. The more decomposed the compost, as indicated by the low C/N ratio, the more easily it is absorbed by the plant. It can play a role as a fertiliser to enhance plant growth. The purposes of adding compost (organic matter) to soil is not only to increase soil nutrient status, but also to increase soil texture and to feed indigenous microorganisms.

Some forest debris, such as litter and sawdust, decompose more easily than sludge. Since compost made of sludge has a higher C/N ratio, it might not increase the height and diameter growth of the seedlings. Compost made of litter gave better results in this experiment.

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EFFECT OF BEHAVIOURAL CHANGES DUE TO HABITAT DISTURBANCE ON DENSITY ESTIMATION OF RAIN FOREST VERTEBRATES, AS ILLUSTRATED BY GIBBONS (PRIMATES: HYLOBATIDAE)

Vincent Nijman

SUMMARY

Monitoring programmes often rely on changes in densities of single species to indicate an ecosystem's health. These densities are estimated by a range of census techniques, including line transects and fixed point counts. Using data from gibbons (Primates: Hylobatidae) the present study demonstrates that habitat disturbance (e.g., logging, encroachment) induces changes in the behaviour of species in such a way that it affects density estimation. As a result of disturbance, gibbons alter their response to humans, change their time budgets, and use different canopy levels. Calling rates are generally lowered in response to disturbance and relatively more calls are given at later times of the day. These behavioural changes alter the detectablity of gibbons, both positively and negatively. The different factors influencing population estimation act in concert and may be difficult to separate to determine their effect. It is argued that in order to improve the effectiveness of monitoring and censussing, the link between behavioural biology and conservation biology should be strengthened.

INTRODUCTION

Behavioural studies have been considered to be of limited value to conservation because of the discordance in the level of focus between behavioural and conservation biologists. Behavioural research focuses on the level of populations and individuals, whereas many conservation biologists claim that conservation is only effective on higher levels of biological organisation (Clemmons and Buchholz, 1997). Hence, in order to be meaningful, conservation research should focus itself on these higher levels. It may, however, be argued that single species can play an important role in monitoring the health of ecosystems when used as indicators. In order to be useful, indicator(s) should, amongst other things, be amenable, reveal meaningful trends, cost effective to monitor, be consistent, and yield data that are precise and unambiguous in its interpretation (GEC, 1998). Primates may meet some of these demands. They are present throughout the tropics over a large range of habitats, occur often in relatively high densities, and fulfil important roles in their respective ecosystems (Smuts *et al*., 1987). Hence, primates have been used frequently in monitoring programmes (Glanz, 1982; Brockelman and Ali, 1987; Johnsand Skuropa, 1987; Whitesides *et al*., 1988).

The two most commonly used census techniques to estimate primate densities employed in monitoring programmes or studies to quantify the effects of habitat disturbance are based on line transects (Sen, 1982; Whitesides *et al*., 1988) and to a lesser extent fixed point counts (Brockelman and Ali, 1987; Brockelman and Srikosamatara, 1993).

The transect technique depends on the detection of animals (or sometimes merely signs such as nests) on one or both sides of a survey path. It has been employed for survey work, where rapid estimates of populations in inaccessible terrain or in widely different geographic areas are required (e.g., Payne and Davies, 1982; Nijman and van Balen, 1998). It is also used for detailed studies within a limited geographic area, including monitoring of temporal changes in density (Glanz, 1982), for comparisons of habitats within the same general area (Johns and Skuropa, 1987; Blouch, 1997; Johnson and Overdorff, 1999), and for estimation of populations in areas where other methods (mark-recapture, complete counts, home range or territory mapping etc.) are not feasible (Green, 1978; Blouch, 1997). When using the transect method the number of groups detected, the effective sighting distance (an estimate of the distance at which the number of sightings at greater distances equals the number 'missed' at nearer distances) and the group spread (defined as the diameter of a circle of equivalent area to that occupied, on average, by a group of the species under consideration) are parameters needed for estimating densities (Whitesides *et al*., 1988). For the method to be meaningful, critical assumptions are (i) animals are not affected by the presence of the observer; (ii) groups are always detected on the transect line itself; (iii) groups behave independently.

Censuses based on fixed point counts are widely used in ornithological studies (e.g., Reynolds *et al*., 1980; Bibby *et al*., 1992) and are especially suitable in rugged terrain. A similar method has been developed to estimate the density of primates producing loud calls at predictable times of the day, e.g., Indri (Indridae), certain colobines (Colobinae), and gibbons (Hylobatidae) (e.g., Kappeler, 1984; Brockelman and Ali, 1987; Brockelman and Srikosamatara, 1993). This method is based on the number of groups that can be heard calling over a given number of days. The observer is situated at a vantage point and notes the number of groups calling within the census area. This method allows density estimation over relatively large areas in a short time span. In order to calculate densities using fixed point counts, parameters needed include the number of groups calling on a given day, the proportion of groups calling on a given day, and the radius of the area from within songs can be mapped (Brockelman and Srikosamatara, 1993). Critical assumptions include (i) only paired groups call; (ii) groups behave independently; (iii) groups call at least once during the study period.

Johns (1985ab; 1986) followed a primate community in Western Malaysia while their habitat was selectively logged. In his study a number of behavioural changes following logging were observed in a number of species, including: (i) Lar gibbon *Hylobates lar* showed a tendency to increase their freezing behaviour and fleeing noisily decreased; (ii) Activity patterns in *H. lar* and Banded leaf monkey *Presbytis melalophos* changed with a significant increase in time spent resting and a significant decrease in time spent feeding and travelling; (iii) For the same two species there was a significant shift from the upper to the middle canopy level for all types of behaviour combined; (iv) During heavy disturbance, gibbons often ceased calling altogether, and calling rates may have remained depressed for several years after logging had ceased. Similar behavioural changes were found by J. Mitani (*in* Berenstain *et al*., 1982) when comparing the singing behaviour of Bornean gibbon *H. muelleri* in forest prior and after the drought and fire associated with the 1982-1983 El Nino Southern Oscillation Event. Population numbers remained unchanged, but audible ranges of songs decreased, frequency of singing declined, and gibbons sang from lower heights.

Since these behavioural changes may be relevant to monitoring and censussing, the present study considers two questions: 1. How and to what extent do primates alter their behaviour in response to human induced changes in their environment (e.g., logging, hunting, encroachment), and 2. Do these behavioural changes affect population density estimates when using either the transect method or fixed point counts?

The implications may be crucial when comparing the results of surveys in habitats differing in their degree of disturbance and in monitoring programmes where disturbance levels change over time. Whether behavioural changes do affect density estimation will be illustrated with examples from studies on different gibbon taxa from the Indo-malayan region, but the conclusions and recommendations are most likely to be valid for other regions and for other rain forest vertebrates as well, including other primates, mammals, and birds.

In order to address the two questions, a comparison is made between the behaviour of gibbons in disturbed and undisturbed situations and the subsequent implications for monitoring are assessed. The behavioural changes can both affect the parameters needed for density estimation and violate the (critical) assumptions of the methods employed.

MATERIAL AND METHODS

Gibbons are territorial and live in monogamous family groups consisting of an adult pair with none to four offspring. Gibbons are completely arboreal, and are largely frugivorous. Paired groups give loud morning calls, which can be heard over several kilometres, whereas single individuals rarely call (Leighton, 1987; pers. observ.). The present study concerns data collected on Bornean gibbon H. muelleri in East Kalimantan (Kayan Mentarang National Park and adjacent areas in 1996 [115°51E, 2°50'N]) and Javan gibbon H. moloch on Java (Gede-Pangrango National Park and adjacent areas in 1994-1999 [107°00'E, 6°45'S], and Dieng mountains proposed National Park and adjacent areas in 1995-1999 [109°35'E, 7°06'S]).

Undisturbed and disturbed study sites were selected either in close proximity and were similar in climate, original vegetation type, altitude and topography (Gede-Pangrango and Kayan Mentarang), or a forest area was sampled before (1995-1998) and during logging (1999) during the same months of the year (Dieng). Given the close proximity and similarity of the forest areas, it is anticipated that the behaviour of the gibbons prior to the commencement of disturbance did not differ significantly. Sets of disturbed and undisturbed areas had mean densities differing less then 10%, which was established by a number of techniques (line-transects, range mapping, fixed point counts). For the present study, disturbance is taken in a rather broad term and may include hunting, encroachment, small scale logging, commercially (selective) logging, or a combination. Behavioural measurements were collected along line transects, on vantage points during fixed point counts, and ad libitum while surveying in the forest. Singing behaviour of at least eleven *H. moloch* groups was monitored in Dieng for 35 days in Sept-Oct 1998 (pre-logging) and for 25 days in Sept-Oct 1999 (during logging). Some additional data on singing behaviour of Siamang H. syndactylus was collected in Way Kambas National Park, Sumatra (1994 and 1999 [105°36'E, 4°50'S]).

For all analyses non-parametric statistics were used (Siegel, 1956) and Yates's correction for continuity was applied in the Chi-sq. tests where appropriate.

RESULTS

1. Behavioural changes affecting line transect censusing

i. *Responses to observers*

The most common response of gibbons to the approach of a human is to flee. This can be accompanied by branch shaking and vocalising. Alternative responses include freezing, i.e., remaining immobile, and hiding, i.e., moving out of the field of vision of the approacher. Vocalisations are normally uttered only when the primates detected humans at close proximity.

Table 1 Behavioural responses of two gibbons species to an observer in disturbed versus undisturbed habitats. Cases where the gibbons did not detect the observer are excluded.

Species **Study site**	**Fleeing plus vocalising**	**Fleeing without vocalising**	**Freezing**	**Hiding**
Hylobates muelleri				
Kayan Mentarang (1)				
undisturbed	20	10	4	1
disturbed	12	8	4	3
Hylobates moloch				
Gede-Pangrango (2)				
undisturbed	12	9	0	0
disturbed	5	5	1	0
Mts Dieng (3)				
undisturbed	60	32	2	1
disturbed	37	24	2	2

1. Undisturbed forest consisted of primary forest in the Nggeng Bio River valley, whereas disturbed forest consisted of 45 year old secondary forest which was situated c. five km south-east in the Bua Alat river valley, East Kalimantan.
2. Undisturbed situation consisted of relatively undisturbed forest in Gede-Pangrango National Park, whereas the disturbed situation consisted of adjacent (smaller) forest patches outside the park boundaries
3. Undisturbed situation consisted of old secondary forest near Linggo, Central Java, in 1998, whereas the disturbed situation consisted of the same forest area in 1999, when a small scale illegal logging operation was in force.

In response to the continued or the increased presence of humans, gibbons alter their behaviour (Table 1). Freezing and hiding and silently moving away becomes more common, though none of the differences are significant (Chi sq., all $p>0.05$). In all three study areas, and for both species, the response was in the same direction, i.e. gibbons tended to behave in such a way as to reduce the likelihood of being detected. Increase in freezing, hiding and silently moving away, makes it more difficult to locate or detect groups of primates and will lead to a decrease of groups detected. It is furthermore likely that group sizes will be under-estimated as it becomes more difficult to detect all individuals in a group.

ii. *Change in activity patterns*

Primates are most often detected when engaged in conspicuous activities such as vocalising, travelling or feeding, either due to visual or auditory cues of the animals themselves or their surroundings (moving of branches, falling fruit etc.). They are less easily detected when resting. Since time spent travelling and feeding is lowered in disturbed forests, this means that fewer groups will be detected in disturbed habitats. This will also include groups at the transect line, violating one of the critical assumptions of the method. Considered in isolation, the observed change in activity patterns will lead to an under-estimation of true densities in disturbed habitats.

iii. *Use of canopy levels*

Gibbons prefer tall trees for certain activities. Emergent trees and the upper canopy are disproportionately used (favoured) for singing and travelling (cf. Kappeler, 1984; Johns, 1986). In disturbed forests, due to the loss of many large trees, generally activities have shifted from the upper to the middle canopy (Figure 1: *H. lar*: Chi sq. = 89.4, df=3, $p<0.01$; *H. moloch*: Chi sq. = 6.10, df=2, $p<0.05$, middle and lower canopy pooled). Since detection probability decreases with increasing distance between the observer and the animal, primates are more easily detected at lower canopy levels. In general, the shift to lower forest strata will lead to an increase of groups detected.

Figure 1 Percentage of canopy use by two gibbon species in disturbed and undisturbed habitats

2. Behavioural changes affecting fixed point counts censusing

i. *Calling rates*

The frequency of calling in gibbons is dependent on, among other things, population density, weather (rain, wind), and seasonality of food production (e.g., Chivers and Raemaekers, 1980; Brockelman and Ali, 1987; V. Nijman, unpubl. data). Disturbance in the form of for instance logging will lead to an increase in ambient temperature in the forest, greater differences in temperature between day and night, and an increase in windiness (e.g., Grieser-Johns, 1997). These changes in the (micro)-climate of the forest can affect calling rates.

Contrary to one of the critical assumptions of the fixed point count method, groups do not behave independently. In the present study it was found that songs were stimulated by neighbours (*H. moloch* and *H. muelleri*), and sometimes songs seemed to pass round the local population (*H. moloch*, *H. muelleri*, and *H. syndactylus*). Lowered calling activity makes detection less likely, whereas estimation of the proportion of groups calling on a given day becomes more prone to errors.

ii. *Distribution of calls*

During a study into an undisturbed population of *H. moloch*, Geissmann and Nijman (in press) noted that some 85% of the female calls and all male calls were given within four hours after sunrise. In disturbed situations, timing of calling changes, with more groups calling later during the day (Table 2). As air heats up during the day locating groups becomes more difficult and the estimation of distance between the observer and gibbons becomes more error prone (cf. D.J. Chivers *in* Duckworth *et al*., 1995). Lowered precision in locating groups may result in two groups calling from the same general direction being recorded as one, whereas the estimation of the radius at which songs can be mapped becomes more difficult. This in effect can influence density estimation in either a positive or negative direction.

Table 2 Number of days *Hylobates moloch* groups were heard calling at different times of the day (Mts Dieng 1998-1999).

	Time after sunrise (hrs)	
Habitat	**<6**	**>6**
Undisturbed	34	1
Disturbed	19	6

Fisher Exact probability test, $p<0.01$

DISCUSSION

The data indicate that gibbons (and probably other primates as well) do respond differently to the presence of humans, including surveyors, in disturbed habitats than in undisturbed habitats (cf. Johns, 1985a; 1986). In the present study, hunting levels were generally low, but high hunting pressure can alter the behaviour of primates to an even greater extend (Kavanagh, 1980; Watanabe, 1981). When conducting line transects, fewer groups will be detected in disturbed habitats as gibbons show an increase in freezing, hiding, and silently moving away. A decrease in conspicuous activities such as vocalising, travelling and eating, as reported by Johns (1985a; 1986), should lead to a decrease in number of groups observed, and may violate the assumption that all groups are detected on the transect line. Only if the decrease in number of groups is unequal for groups on the transect line and groups located farther away, in such a way that groups on the transect line are still always recorded, a decrease in groups detected will not necessary result in a reduction of estimated density (Skorupa, 1987). However, as there is no indication whatsoever that the number of groups detected on the transect line itself will not have decreased, one of the critical assumption of the line transect method is violated. This will lead to an under-estimation of true densities. Under-estimation of true densities will be even stronger when indeed actual group sizes are under-estimated owing to the increased difficulty in counting individuals. However, not all behavioural changes by gibbons will lead to an under-estimation of true densities, since the marked increase in the use of the lower to middle canopy over the upper canopy in disturbed habitats makes it easier for an observer to detect gibbons.

Calling frequency in gibbons is dependent on a number of environmental variables, including population density, weather, temperature in the forest, and seasonality of food production (Chivers, 1974; Kappeler, 1984; Brockelman and Srikosamatara 1993; V. Nijman unpubl. data), which all might be affected by habitat disturbance. Logging will induce changes in the micro-climate of the forest including an increase in ambient temperature, greater differences in temperature between day and night, and an increase in windiness (e.g., Grieser-Johns, 1997). Habitat disturbance may also alter the acoustical environment on which organisms rely for communication (Clemmons and Buchholz, 1997). Increase in windiness will lead to a significant decrease in calling (*H. pileatus*: Brockelman and Srikosamatara, 1993), and changes in the ambient temperature may affect pre-dawn calling by males in two species (*H. klossi* and *H. moloch*), as pre-dawn calling in male Kloss' gibbons is positively related to temperature (Whitten, 1982).

Contrary to one of the critical assumptions of the fixed point count method, groups do not behave independently. Songs were stimulated by neighbours (cf. *H. lar*, Raemaekers and Raemaekers, 1985), and songs seemed to pass round the local population as has been reported in other studies (Brockelman and Ali, 1987). Fixed point counts are furthermore affected by a depression of calling rates during the day, and possibly by an increase in pre-dawn calling. Lower calling rates make detection less likely, and calls given later during the day makes distance estimation more difficult.
Similar to the studies conducted by Johns (1985ab; 1986) and J. Mitani (*in* Berenstain *et al*., 1986), the present study compared the behaviour of primates in areas where the true density was either very similar or had remained virtually the same. Effects of a lowered (or increased) density were not taken into consideration. Habitat disturbance often has an effect on density, due to a lowered carrying capacity of the forest, lowered fecundity, higher mortality (aggravated by an increase in hunting), and sometimes due to groups migrating out or into an area. Lowered densities will introduce additional changes in the parameters needed for density estimation, including smaller group spread for smaller groups, smaller effective sighting distance due to reduced group sizes (e.g., van Schaik *et al*., 1983; V. Nijman unpubl. data), and a disproportionate reduction of calling rates (V. Nijman, unpubl. data). Alternatively, locally habitat disturbance may lead to larger group sizes and higher densities. In degraded forest with a discontinues canopy the obligate arboreal nature of many primates, and gibbons in particular, does not permit them to move from one remnant forest patch to another. This induces delayed dispersal of sub-adults, leading to larger group sizes and (temporarily) higher densities (e.g. Brockelmann *et al*. 1998; Oka *et al*. 2000).

Comparing census data from habitats differing in degree of disturbance should be viewed with caution and conclusions should be drawn with care. The mere observation that certain animals are more/less often recorded in these different habitats in itself carries little information. Hence, comparisons of abundances of vertebrates in disturbed and undisturbed situations based on encounter rates only, as done extensively for example by Grieser-Johns (1997) when reviewing the responses of vertebrates in relation to timber production and biodiversity conservation in tropical rain forests, becomes in effect meaningless.

CONCLUSION

Habitat disturbance clearly alters the behaviour of gibbons, and probably many other vertebrates, in such a way that it affects density estimation. Behavioural alterations may be species specific, but may also be related to the types of disturbance, such as the presence or absence of hunting / capturing. Different factors influencing population size estimation act in concert, and may be very difficult to separate to determine their net effect. When comparing census data from habitats differing in their degree of disturbance, the effect of behavioural alterations should be recognised and conclusions drawn with care. It is concluded that there is an increased need for understanding the behavioural plasticity of indicator species, and behavioural studies should play a more prominent role in conservation. Strengthening the link between studies in behavioural biology and conservation biology is needed for improved monitoring and censusing (cf. Beissinger, 1997; Clemmons and Buchholz, 1997).

ACKNOWLEDGEMENTS

I wish to thank the Indonesian Institute of Sciences (LIPI), the Directorate General for Forest Protection and Conservation (PKA) and the Ministry of Forestry and Estate Crops (MOFEC) for allowing me to conduct this research. In this, the help of the Museum Zoologi Bogor, and especially Dr D.M. Prawiradilaga is kindly acknowledged. Financial support for the study came from the Netherlands Foundation for International Nature Protection (Van Tienhoven Stichting), Society for the Advancement of Research in the Tropics (Treub Maatschappij), and Stichting het Kronendak. Dr H. Albrecht (formerly Dept. of Animal Behaviour, University of Amsterdam) was instrumental in offering insight into the links between ethology and primate conservation. Dr P.J.H. van Bree (Zoological Museum Amsterdam) is thanked for his help throughout the project. Prof. Dr S.B.J. Menken and Dr A.Ø Mooers (ISP /ZMA, University of Amsterdam) gave valuable comments on a draft of this paper.

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The Role of the Indonesian Forest Concessionaires in Research and Development on Forestry in Indonesia

Muhandis Natadiwirya

SUMMARY

The Indonesian Forest Concessionaires Association, as a forum for actors in forest utilisation, has a moral responsibility to manage forest resources in such a way that both present and future generations can enjoy the benefits. The **vision** of APHI's research and development is to make research and development activities the basis of forest management policy making. This is also in line with the **mission** of APHI, which is to support any aspect of research and development to improve the performance of forest utilisation, taking into account production, environmental and social functions. APHI's strategy to be implemented as carrying out Research and Development, especially on the important andstrategic aspects, in collaboration with other institutions, acting as the government's partner in Research and Development, motivating and monitoring Research and Development activities by APHI members, Disseminating Research and Development results and participating in collaboration with any partner coming from either the home or foreign countries. APHI's contribution will be to support R and D activities in Wanariset Samboja, the growth and yield clearing house in FRIS-DfID and BFMP, and the universities, and to collaborate with international organisations. APHI's future policy on Research and Development is based on its Vision and Mission and is directed towards encouraging the implementation of sustainable forest management. In order to strengthen the research and development network, APHI is open to any parties who are willing to collaborate with it.

BACKGROUND

The forestry sector has played an important role in supporting national development. This is based on the fact that two thirds of the Indonesian land area is forest and that the sector makes the biggest contribution to the Indonesian foreign exchange among the non-oil and mineral sectors. In order to use the forest resources, the Indonesian government grants forest concessions to companies to realise the economic value of the forests. The Indonesian Forest Concessionaires Association (Asosiasi Pengusaha Hutan Indonesia, further referred to as APHI), as a forum for the actors in forest utilisation, has a moral responsibility to manage forest resources in such a way that both present and future generations can enjoy the benefits. This can be achieved only by applying conservation-based approach, which encourages well-planned and integrated research and development activities in collaboration with other relevant parties. The ***vision*** of APHI's research and development is to make research and development activities the basis of forest management policymaking. This is also in line with the ***mission*** of APHI, which is to support any aspect of research and development which seeks to improve the performance of forest utilisation, taking production, environmental and social functions into account.

FUNCTION AND ROLE OF APHI'S RESEARCH AND DEVELOPMENT

1. Acting as the government's partner in research and development activities and proactively providing inputs to the government in policymaking.
2. Doing research and development activities, especially on the important and strategic aspects, in collaboration with other research and development institutions.
3. Motivating and monitoring research and development activities implemented by other institutions which can benefit members of APHI and the public generally.
4. Disseminating research and development results to members and the public through scientific forums such as workshops, seminars, discussions and other information media.
5. Participating in any collaboration with any partner coming from either the home or foreign countries.

APHI'S CONTRIBUTION

1. Collaboration with the *Department for International Development* (DfID) in Forestry Research Institute, Samarinda (1997-1999)

   The collaboration was started on July 1, 1997 by sending two members of staff to join the activities of the *Growth & Yield Data Clearing House*. This activity is the most prominent, considering that so far data on increment has not been used as an instrument for sustainable forest management. The data on increment used so far has resulted from assumptions and has not come from scientific analysis. The activities include:

   - Monitoring data on Permanent Sample Plots (PSP) in the Kalimantan region.
   - Assessment of data quality in the forest concessions' PSP.
   - Establishing a growth & yield data system.
   - Comparative study on the Symfor & Dipsim modelling programs.
   - Training on the establishment and measurement of PSP.
   - Joining scientific forums on growth & yield

   This Growth & Yield project with the DfID ended in August 1999 and will be continued by the Bureau of Forest Management Project (BFMP) in Tajung Redeb. APHI has seconded one member of staff to be involved in the continuing project.

2. Research and Development in collaboration with other institutions:

   a. Tangjungpura University, Pontianak (1992-1999)

   The activity carried out jointly with Tanjungpura University was the establishment of a research centre for *In-situ* Ramin (*Gonystilus bancanus*) conservation in West Kalimantan. The collaboration itself had started on December 26, 1991, based on the MOU No. 440/APHI/0892, issued on August 7, 1992. It went on for five years. In the process. the collaboration was extended and revised with the focus on *"Peat Swamp Forest: Ecosystem, Conservation and*

b. Gajah Mada University (1990-1995)

It was intended to establish a pilot project for rattan cultivation in the Education Forest of Gajah Mada University. The collaboration commenced on April 12, 1990 for two to five years. The activities included the establishment of a working station (50 m^2), the supply of various rattan seedlings (22,700 seedlings) and rattan planting activity on an area of 50 ha.

c. Oxford University, UK (1997-2000)

This joint research focused on the conservation biology of wild boar in North Sulawesi. This joint research started in March 1997 and will end in March 2000. The activities comprise a survey of the distribution and concentration of protected wild animals and a proposal to the government to protect the habitat in North Sulawesi. The survey has been repeated several times by Dr. Lynn M. Clayton (a researcher of Oxford University) accompanied by [his/her] APHI counterpart. The result of the survey was the designation of 32,500 ha as a protected area for wildlife purposes in Adudu, Gorontalo District, especially for the area of wild boar concentration.

d. Tropical Forest Foundation (since 2000)

The collaboration focussed on the implementation of low-impact logging in Indonesia. The collaboration has so far reached the stage of signing the MOU. The project will be effectively implemented in February 2000. To strengthen the research, there will very likely be collaboration with other institutions such as CIFOR, the universities etc.

e. International Counterparts (since 1999)

The research is being conducted into the implementation of reduced impact logging, conservation & biodiversity. It is related to the production of greenhouse gases by United States' industries, which are committed to reducing greenhouse gases by paying developing countries to develop activities mitigating the emissions, such as reduced impact logging, conservation & biodiversity. The MOU has been signed by both parties. APHI has distributed information to invite competent parties to become involved in this project.

3. Participating actively in scientific forums as seminars, workshops and other discussions related to the activities of research and development or research organisations, such as CIFOR, LIPI, CSIRO etc.

COLLABORATION WITH THE TROPENBOS-KALIMANTAN PROJECT IN WANARISET SAMBOJA, BALIKPAPAN, EAST KALIMANTAN (SINCE 1989)

Collaboration between the APHI and the Tropenbos-Kalimantan Project is based an agreement between the APHI and the FERDA of MOFEC, legalised by the letter of the FERDA, no. 31/Piagam/VII-TLII/1989, dated October 16, 1989.

The activities were formally commenced on November 14, 1989, on the basis of the MOU signed by APHI and the FERDA of MOFEC. The APHI has contributed a pilot project unit of Dipterocarpaceae, a nursery embankment with an area of 991 m^2, 8 boxes of beton stek, 2 boxes of ulin cuttings, a seed orchard with an area of 680 m^2 and an office of 96 m^2 in the Wanariset Samboja Research Station. This research station had been finished in 1991. Other activities included the promotion of multiple-use plants such as aren (*Arenga pinnata*) to people living around the research station, the rehabilitation of orang-utan and the adoption of 15 orang-utans by forest concessionaires.

In addition, APHI contributed the operational costs of the research and had APHI staff working directly in Wanariset Samboja. APHI has sent 11 staff to work in Wanariset and there have been 3 APHI researchers working directly so far, one of whom is doing PhD research. They have been doing research on:

- Agroforestry & Social Forestry
- Biodiversity & Forest Ecology
- Economy,
- Forest Rehabilitation

FUTURE POLICY ON RESEARCH AND DEVELOPMENT BY APHI

The future policy is based on APHI's vision and mission and is directed towards encouraging the implementation of sustainable forest management [towards eco-labelling era?], such as growth and yield, reduce impact logging, low impact logging, code of harvesting, genetic resources, conservation & biodiversity etc.

Growth and yield is still the Research and Development programme with the highest priority, because increment data on are not yet available. The existing data are from estimates or assumptions not based on scientific analysis.

CLOSING REMARKS

In view of the importance of R&D in APHI, this division will improve their role in sustainable forest management. To strengthen the research and development network, APHI is open to any parties who are willing to collaborate with it.

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INCREASED COMMUNITY PARTICIPATION IN FOREST MANAGEMENT THROUGH THE DEVELOPMENT OF SOCIAL FORESTRY PROGRAMMES IN INDONESIA

Sri Suharti

ABSTRACT

In the last few years there has been a tendency to adopt a new forest management system in which people's participation is the focus of attention. This concept has several different names, such as community forest based management, collaborative forest management, joint forest management and social forestry. Three main principles are applied in this new forest management system i.e. 1) Local people need to be involved in forest management activities; 2) Local people have legal rights and obligations to participate in forest management activities; 3) There is a need to actively involve local people in deciding on which activities to develop in order to guarantee a forest management system which is economically feasible, socially adaptable and ecologically sound.

To anticipate the tendency, the Indonesian Ministry of Forestry and Estates (MOFEC) has developed several programmes the main purpose of which is to rationalise and empower the life of local people living near and around the forest area and to increase their participation in forest management activities. There are various forms of social forestry programme in Indonesia i.e. PMDH (Forest Village Development Programme), Community Forestry, Mixed Farming Timber Estate, Transmigration Timber Estate, Small Scale Private Forest, etc.

Social forestry programme development shows a dynamic from time to time Since the programme was first introduced there has been a change of heart on the part of professional foresters, who in the past mostly thought they knew more and had a greater right over forest resources. Now they realise that local people also have the right to be involved in forest management activities. Furthermore, the active participation of the people in forest management activities has an important role in determining the success of sustainable forest management. The top-down approach as the only method applied in programme establishment is now being gradually abandoned. The newly introduced method of PRA (Participatory Rural Appraisal) is starting to be used widely in designing alternatives in social forestry programmes.

This paper tries to elaborate the establishment of these programmes and to describe how far and in what activities local people could participate in forest management activities in some areas of Indonesia. Some case studies presented in the paper focus on what the local people receive and how they react after the establishment of these programmes. The information presented here has been gathered from several research studies and literature.

I. INTRODUCTION

Forestry in Indonesia has followed two different management approaches. One approach is the management of the surrounding forest land by forest dwelling communities and individuals. The other one is the management of state forest by the government. There are some differences between these two management approaches, resulting from different cultural presuppositions about resource management and control. This situation gave rise to some conflicts between forest village people and the government over forest land use (Poffenberger, 1990). During the past two decades, the occurrence of social conflicts between these two parties has become more frequent, especially after the government of Indonesia decided to give concession rights to concessionaires. These concessionaires (who were most likely newcomers) assumed that they had greater power and rights to exploit the forest, as they had a formal licence from the government. Local people, who have been living in the area since time immemorial, are considered to be outsiders who will disturb and endanger the concessionaires' activities. Moreover, local people wonder why after these newcomers come into the area, they are no longer allowed to work or take anything from the forest.

Learning from the situation the government of Indonesia (GOI) realised that this had been an inappropriate approach to forest management. Local people, who had been living in the area long before the concessionaires came, should be involved in forest management activities, as otherwise there would be constant conflict between the two and this situation in turn would endanger forest resources.

Furthermore, there has been a change in the last few years in many parts of the world towards a new forest management system based on participation of the local people. This concept has various names, such as community forest based management, collaborative forest management, joint forest management and social forestry. Three main principles are applied in this new forest management system *i.e.* 1) Local people need to be involved in forest management activities; 2) Local people have legal rights and obligations to participate in forest management activities; 3) There is a need to actively involve local people in deciding which activities to develop in order to achieve a forest management system which is economically feasible, socially adaptable and ecologically sound (Lembaga Alam Tropika Indonesia/LATIN, 1998).

In order to anticipate the change towards a new forest management system and also to reduce the occurrence of social conflicts, the Ministry of Forestry and Estates (MOFE) has developed several programmes with the main purpose of rationalising and empowering the lives of local people living in and around the forest area and of increasing their active participation in forest management activities. There are various forms of social forestry programme in Indonesia *i.e.* PMDH (forest village community development programme), community forestry, transmigration timber estate, mixed farming timber estate, small-scale private forest, etc.

This paper tries to give an overview of the establishment of some of these programmes and to describe how far and in what activities local people can participate in forest management activities. Some case studies presented in the paper focus on what the people receive and how they react after the establishment of these programmes. The information given here has been gathered from several research studies and literature.

II. THE IMPLEMENTATION OF SOCIAL FORESTRY PROGRAMMES IN INDONESIA

Social forestry is defined as the practice of using trees and/or tree planting specifically to pursue social objectives, usually betterment of the poor, through the delivery of benefits (of tree and/or tree planting) to the local people; it is sometimes described as "tree growing by the people, for the
Nair, 1993)

Another author has noted that the meaning of social forestry cannot be gathered from descriptions of the range of activities carried out under the projects. As Noronha and Spears, in Sutrisno (1990), have indicated, the novel element of social forestry projects is that these serve local needs through the active participation of the beneficiaries in the design and implementation of the reforestation efforts and the sharing of products. This would imply that the success of social forestry programmes depends on the responses of persons living in the forest based communities, made up of "individuals who have a lot in common and yet unique differences".

People's participation in social forestry programmes must be preceded by the creation of a participatory environment. This leads to two basic questions *i.e.* what kind of programme and how far are people expected to participate in it, and how does the Forestry Department propose to create a participatory environment in the implementation of the programme. Depending on how we define the word "participation". Sen and Das, in Sutrisno (1994), suggested two possible alternatives to increase people's participation in social forestry programmes. The first alternative is to look at the major operating tasks in social forestry and consider at what stage people could participate. The operating tasks are; 1) nursery raising; 2) land preparation (digging of pits); 3) watering; 4) weeding; 5) fertiliser application; 6) protection from pests and diseases and 7) exploitation. This kind of participation is considered to be the lowest level of participation, as the people become involved in forest management only as wage labour and the Forestry Department continues to decide and determine all forest management activities (P3AE-Universitas Indonesia, 1998).

The second alternative is to involve people in all the major management functions of forest management activities, starting from the planning stage right up to product marketing. These activities include: 1) land selection; 2) species selection; 3) organising planting operations; 4) plantation management (maintenance and protection); 5) exploitation and marketing. These functions have to be carried out by the people themselves with the Forest Department contributing technical assistance.

In the past, the implementation of social forestry tended to apply the first alternative. Under this "top-down" approach the people act merely as an object and have no right to make any suggestion about forest management activities. All the decisions are made by what we call "professional foresters". Only in the last few years has the GOI begun to realise that the approach used in the programmes should be changed in order to give greater opportunities for the people to play a role in forest management activities.

III. HISTORICAL REVIEW OF SOCIAL FORESTRY PROGRAMMES

Long before the term “social forestry” became popular and encouraged many people to learn more about it, Perum Perhutani (State Forest Enterprise) was the local people taking into consideration and involving them in forest management activities. This effort aimed at the attainment of sustainable forest management and at improving the social welfare of the people living around the forest as well.

In the early 1970s Perum Perhutani introduced what was called the prosperity approach programme in Java. It was followed in 1974 by MA-LU and in 1982 by the PMDH programme (Forest Village Community Development Programme). MA-LU stands for Mantri and Lurah, meaning forest ranger and village chief. This programme addresses, in particular, the importance of cooperation between forest ranger and village chief in the implementation of the prosperity approach programme, in particular, in greening activities on village land and in forest protection (Perum Perhutani, 1982). In 1982, the programme was further developed more and became the Forest Village Community Development Programme (PMDH). This programme, which was actually an extension of the prosperity approach programme aimed to promote employment, increase villagers’ income and distribute it more equally, enhance the growth of the village economy, promote a balanced standard of living between rural and urban communities, encourage sustainable forest management and forest use and enhance the capabilities of villagers in general (Perum Perhutani, 1982).

The application of the “prosperity approach” programme, using extension methods can be categorised as “top-down”. This management approach was improved in the MA-LU programme, although the extension methods were still “top-down”, with the implementation being carried out jointly by Perum Perhutani field personnel and local government officials. All the efforts and initiatives (including funding) for the programme came from the top management of Perum Perhutani.

The social forestry programme on forest land was initiated in 1984 by the Directorate General of Forest Utilization and Perum Perhutani of the Ministry of Forestry, and supported the by Ford Foundation. From October 1984 to early 1986 diagnostic research was carried out in Java with Perum Perhutani (State Forest Enterprise) as the implementing agency. This research was followed by pilot projects in Java. The organisation and execution of the programme seem to have been better than those of the previously mentioned programmes, with more involvement of various groups and calling on the expertise in society. An important aspect of this programme is the effort to organise and educate forest farmers with the objective of creating an partnership between Perum Perhutani and the villages participating in the programme. This goal is to be achieved by the establishment of forest farmers groups, which are expected to become a medium for a two way communication between foresters and farmers using both the “top-down and bottom-up” approaches (Kartasubrata, 1990).

In 1986 the first phase of the “Outer Islands Social Forestry Programme” was initiated. This programme is coordinated by the Directorate General of Forest Utilization in cooperation with the respective regional government and forestry offices. Local universities and voluntary organisations collaborate in the implementation of the programme (Nasendi, 1990).

From time to time, modifications, adaptations and changes are made to the implementation of social forestry programmes. Since 1990, the GOI has been urging concessionaires to become more actively involved in social forestry programmes. The implementation of a social forestry programme is then integrated with timber estate establishment (TE). Under Ministry of Forestry decree No. 20/II/1983, all concessionaires have to establish timber estate plantations . As a reforestation activity, the objective is to increase the capacity of the forest and thus guarantee the sustainability of industrial timber supplies. The development of the timber estate is carried out by the concession holder with funding from the Reforestation Fund (DR). The establishment of the programme in an area should allow some direct or indirect input from the people living in and around it. it The community is therefore expected to receive some benefit from the establishment of the plantation. Timber estate establishment often involves people (usually shifting cultivators) who live around the site as well as transmigrants in the area. The degree of involvement of these people in the plantation varies depending on the policy of the company. Some of them participate very minimally in company work as general labourers, while others are more involved in the plantation. Learning from this situation, timber estate development companies have started trying to increase active participation by adopting modified models of TE such as mixed farming TE and transmigration TE. Nowadays, companies in charge of developing TE are beginning to balance wood production and the social welfare of the people involved in the programme. Hence, these people not only receive wages, but also other benefits such as improvements in marketing and health facilities, infrastructure and other forms of subsidy (Gintings and Suharti, 1998).

In order to ensure that concessionaires paid more attention to local people living in and around the concession area, the GOI, through Minister of Forestry (MOF) decree No. 691/Kpts-II/1991, subsequently instructed all concessionaires to become actively involved in empowering local people and this is now obligatory. A programme called HPH-PMDH (Pembinaan Masyarakat Desa Hutan) for increasing people's participation was established in 1991. All concessionaires have to develop and supervise at least 2 (two) villages under the HPH-PMDH programme, which addresses the problem of poverty, especially for those living in and around their concession area. If they do not apply the programme, they are penalised by MOF, *i.e.* refusal to approve the annual cutting plan.

IV. COMMUNITY PARTICIPATION IN SOCIAL FORESTRY PROGRAMMES

The concept of community participation is not fully satisfied by "just" receiving people's contributions in the form of labour, kind or cash. Participation must contain elements of initiative and decision, emanating from the community itself. When community contributions do not comprise such bottom–up elements, the concept changes from participation to mobilisation (Nasikun, 1990). As has already been mentioned, there is a wide range in the degree of people's participation in forest management activities. The extent to which companies seriously support community participation depends on how far they are aware of and understand its importance and on how far they are willing to transfer some of the profits gained during their operations in the area and to the local people living around their concession. The participation of people in mixed-farming TE, transmigration TE (TTE) and HPH-PMDH programmes is presented in detail below.

a) Participation in Mixed-farming Timber Estates

Some concession holders have already applied the mixed farming technique in the establishment of plantation forests. This approach is much better for both parties (the company and the labourers). By working on the plantation, people earn some wages and also have a chance to grow food crops between the rows of trees. However, the permit to grow food crops is only for 1–2 years, that is before the tree canopy becomes so wide that crops no longer grow well. After 1–2 years they have two possibilities, *i.e.* to look for another job or to extend the contract if the company wants to establish TE in another area. Nevertheless, this programme has so far already provided a chance for the people to receive a regular monthly wage and an opportunity to grow crops for their own consumption (Suharti, 1993).

The company actually loses nothing from the application of mixed-farming TE, in fact, some studies reveal that growing food crops among the trees has positive effects on the growth of the tree. Kijhar, in Sukandi (1990), reported that the growth of trees when grown together with food crops tends to be better than those grown without food crops. Similarly, Mile (1992) found that (4) four species of trees in mixed-farming TE in HPH. PT. Erna Djuliawati, *i.e. Acacia mangium. Paraserianthes falcataria*, *Eucalyptus deglupta* and *Gmelina arborea*, showed better growth than those grown without it. Besides, monthly wages, this pattern could also contribute to households' income from rice and other food crop production. Meanwhile, PT. Inhutani V in Bengkulu and Lampung, which also applied this programme, reported that farmers are allowed to grow rice, corn and other food crops for (3) three years. In this case, these crops are grown under rubber trees and, on average, each hectare could produce 3.5 tones of unhulled dry rice/year.

This type of interaction is not yet universal, but at least some concessionaires have already paid some attention to local people living round the concession area and tried to give them a chance to earn additional income from TE activities. Some modifications are indeed needed to increase the self-reliance of the people, so that they do not fully depend on the company and are able to create their own jobs to guarantee their livelihoods in the future. The concessionaires could give them some subsidy or other form of assistance, such as food crop seeds, fertiliser, extension, training, etc. as they usually also own some land which they cultivate themselves. This would help them to work more effectively in managing their land and finally be able satisfy their basic daily needs. The responsibility of deciding what kind of subsidies and how they should be given is not only in the hands of the concessionaires, but should be coordinated with the Ministry of Forestry and Estates, Ministry of Agriculture, local government and other institutions in order to increase the self-reliance of the people and achieve top quality TE plantations (Gintings and Suharti, 1998).

b) Participation in Transmigration Timber Estates (TTE)

Indonesia's forest policy is closely linked with other pioneering efforts such as the transmigration programme. In TTE, settlers are given permanent employment at the Eimber Estate on Indonesia's outer islands. Eventually, every forest concession will have its own TTE project. Providing a job for each family head involved will, over the years, save many hectares of forest which they might otherwise destroy to obtain land to grow food crops.

In 1991, Transmigration Timber Estates (TTE) started to recruit people, mostly slash and burn migrant cultivators. Now more than 111 TTE units are being established throughout the country (Manan, 1995).

The establishment of TTE could be done by using 2 (two) kinds of model *i.e.* Integrated TTE, and TTE using the NES (Nuclear Estate Smallholder) pattern.

1. Integrated TTE

The development of TTE is designed together with the development of a transmigration settlement, either inside or outside TE unit; most of the transmigrants' income comes from forest plantations. Transmigrants work in the TTE during the year and obtain an adequate income, while the company has permanent labourers to cultivate the plantation continuously. The regulation of contractual arrangements between the two parties should be mutual.

In integrated TTE, people also receive additional benefits to their daily wage *i.e*. an opportunity to cultivate the land for food crops, as long as it does not disturb tree growth on TE (similar to mixed-farming TE) and an opportunity to develop plantations of seedlings under the village unit cooperative (KUD) guides, so that later they will be able to supply seedlings to the company.

2. Transmigration timber estates using the NES pattern

The development of the plantation in this pattern is also related to the transmigration programme. The plantation unit is considered to be nuclear, while the transmigrants in the settlement areas are considered to be smallholders. An example of this pattern can be found in North Sumatra in HPH. PT. Indorayon. This type of TE imitates the NES-Trans programme, which was developed earlier by the Ministry of Agriculture. Forest areas converted to smallholder areas cover at least 4 (four) ha (a share certificate is issued for each smallholder). Besides this, each transmigrant receives a 36 m^2 house and 0.50 ha of home garden. But some further considerations have to be taken into account, *i.e*. transmigrants are allowed to keep the trees well until harvesting time (8 years for pulp species and 18 years for construction timber). There is also the possibility that, after the trees are cut, the transmigrants will not be willing to grow trees any more and so the area of production forest will decrease.

c) Participation in HPH-PMDH programmes

The HPH-PMDH programme could be defined as the social activity of the concession holder (HPH) in managing shifting cultivation living within and around concession area towards sedentary farmers and other productive activities based on conservation principles (Dit. Penyuluhan, RRL, 1991).

The activities developed in HPH-PMDH programmes are adapted to the physical condition of the area, the socio-economic and cultural situation of the people and the needs and desires of the people. Alternative activities developed in PMDH programmes include:

1. Permanent/sedentary farming
   (rice field cultivation, dry field cultivation, provision of production factors, extension, dams/building irrigation facilities).
2. Increase in income generation
   (labour recruitment, home industries, credit for livestock raising, etc)
3. Infrastructure provision
   (houses, road, bridge, school buildings, health facilities, etc).
4. Socio-cultural development
   (training and education, sport, fellowship, religion, art etc).

5. Conservation forest and natural resources
   (reforestation, terracing, small scale private forest, extension)

Community participation in HPH-PMDH programmes in some provinces in Indonesia is elaborated below:

a. HPH-PMDH in Riau Province

The development of HPH-PMDH in Riau province is relatively small scale (in terms both of number of participants and area of coverage). To take the example of HPH PT. Sejati Riau I, on average in one year, they involve only 10 households. This also applies to HPH PT. Triomas FDI, where only 30 households participate in the programme each year. Activities developed in the programme vary from providing some form of subsidies, up to the provision of houses for each household (in Triomas). However, most of the activities developed are only for one year and, after that, HPH moves to another group or another area. The reason why HPH do it is because establishing the programme is compulsory for them. Moreover, each concession has to develop at least 2 (two) villages every year and, within 20 years, or after their concession terminates, all the villages in their concession area must have been involved in the programme. This situation makes them try to achieve the target of developing villages and not concerning themselves with the continuation and the appropriateness of the programme to its participants. Failure to continue programme development means that efforts to involve local people in forest conservation activities fail. To take an example, the people may be given some instruction in nursery activity but they are told nothing about cultivation and maintenance techniques. Again in Sejati Riau I, people are encouraged to grow pineapples on their land, as the area is suitable for pineapples, but unfortunately HPH does not provide the people with techniques to conserve the product. As a result, when the amount of the product is abundant during the harvesting period, the price becomes very low and, since pineapples are perishable, they have to be marketed quickly at any price. If HPH told them about conservation techniques, they would not need to sell them quickly, as they could keep them and market them later at a better price (Suharti *et al.*, 1995).

In the area, groups of farmers who should be empowered do not reach their full potential. The guidance and extension are given more individually. This is of course ineffective because, if there is problem (technical or non technical), they have to go to the extension officer individually. Moreover, there is another problem for product marketing, since marketing the product individually means the farmer has no power to determine the price. If they worked and marketed their product as a group, they could negotiate together and decide on a selling price (Suharti *et al*., 1995).

Professional extension officers are not available in these two concessions. Field experience has shown that extension officers, who should understand not only the technical problems, but also the socio-economic-cultural situation of the people, are not doing their job well. Many of them are even outsiders who have not originated from the area, and so they do not understand the socio-cultural situation of the people (Suharti *et al*., 1995).

The method used in deciding which alternatives to develop is based on a “top-down” approach. Everything is decided by the concessionaires and the people passively accept everything given to them. n gauging the success of the programme, we found that the people felt unsatisfied about it and, since the activities offered by the programme do not consume most of their time and labour, some of participants still continue to practise shifting cultivation.

b. HPH-PMDH in South Kalimantan province

Not all the 11 forest concessions operating in South Kalimantan province have developed a HPH-PMDH programme regularly each year. In 1998/1999 there were only (4) four forest concessions who implemented the programme (Kanwil kehutanan Propinsi kalimantan Selatan, 1999). The scale of programme development is relatively bigger than in Riau. For example, HPH. PT. Yayang involved 200 households, while HPH.PT. Hutan Kintap involved 180 households and HPH. PT. Kodeco 100 households. The concession allocates between 0.5 – 1 Ha of forest land to each participant to cultivate. All the participants in these three HPH are divided into farmer groups of 20–30 people. Farmer groups are already functioning well and helping to facilitate the development process. Before the programme is executed, the concessionaires carry out “a diagnostic study”, to investigate the potential of the area (biophysical, socio-cultural situation). Intensive dialogues and discussions about alternative activities are conducted. In these dialogues and discussions people are asked about their expectations and needs (Suharti, 1993).

Although people are already involved in designing the programme, so far they are still in an inferiority position. It is the concessionaires who analyse, define and determine alternative solutions to their problems. Alternative activities developed in the programme already covers all 5 (five) of the possible activities suggested, but unfortunately not all the activities were done well. Dam building in HPH. PT. Hutan Kintap, for instance, could not function properly as the dam was poorly built. It seems that the concessionaires only try to achieve the programme target and give less thought to the technical feasibility of the area. This also happened in HPH. PT. Yayang, where social conflicts arose after the concessionaires suggested that people should grow sungkai (*Peronema canescens*) on their land ,while people were reluctant to do so. They were unwilling to grow because they prefer to grow other species (fruit trees and estate crops). The people consider it would be more advantages to grow these species than sungkai, as fruit trees and estate crops would be able to contribute some of their basic necessities, while if they grow sungkai, the concessionaires who would derive the benefit. In addition, the people consider that sungkai is still available in the forest, so why should they grow it? (Suharti, 1993).

Here it can be seen that concession holders seem have not taken into account the needs and desires of the people. The purpose of the programme establishment to improve the social welfare and self-reliance of the people is not being met. The people are considered only as a means to achieving their goal of getting the timber product. Although developing the programme is compulsory, with a risk of penalty for all concessionaires, they are still not aware of the importance of the active participation of the people, and this results in the failure of the programme establishment. The situation is sometimes worse when the extension worker, who should be the mediator between the two parties, failed in his task and even complicated the conflict .

c. PH-PMDH in West Kalimantan province

Of the 45 forest concessions operating in West Kalimantan, only 33 have developed HPH-PMDH activities. In this province, the scale of programme activities varies from relatively small (HPH. PT. Halisa) to relatively big (HPH.PT.Erna Djuliawati). In Halisa, the programme involves only 20 households in each village (there are two villages in the HPH-PMDH programme). The activities include provision of production input (seeds, fertiliser, equipment), plot demonstration of annual and perennial crops, provision of health and education facilities, bridges and roads (Suharti *et al.*, 1999).

By contrast, in Erna, the programme already involves a relatively large number of households (150 households involved). The activities include guidance on rice field farming and the promotion of rubber tree growing in their former shifting cultivation area. Other activities are the provision of credit for livestock raising and transport facilities to surrounding villages (Suharti *et al.*,1999).

Both in Halisa and Erna, before alternative activities were selected, there was already communication between the people and HPH. In order to encourage the people to be more participatory, both HPH already applied the PRA (Participatory Rural Appraisal) method, so that it is the people themselves who evaluate, identify and diagnose their problems and select alternative solutions which they consider to be the most appropriate. HPH personnel were also present during the process, but they acted more as facilitators and offered help only when there were difficulties or confusion in selecting activities.

Looking at the process of HPH-PMDH establishment, it can be seen that much progress has been made in the social forestry programmes. The “top-down” approach, which was considered to be the most suitable method of programme implementation, has slowly been replaced by a combination of the “top-down” and “bottom-up” approaches. Companies’ awareness
participation seems to be increasing. However, the situation needs intensive monitoring and evaluation by the Ministry of Forestry (*c.q.* regional Forest Service). Because otherwise the companies might again consider the development of the programmes only as another burden for them and therefore useless. If possible, training about the importance of community participation and how to promote it should also be given to the personnel of HPH.

V. CONCLUSIONS AND RECOMMENDATIONS

It can be seen from the above that from time to time there is a dynamic in social forestry development. Beginning from when social forestry was first introduced, it showed there has been a change of attitude among professional foresters, who mostly thought they know more in the past and had more rights over the forest. They started to realise that local people also have the right to be involved in forest management, and that community participation also has an important role in determining the success of sustainable forest management. Local people’s feelings and knowledge which were often neglected before, began to receive some attention after it was realised that indigenous knowledge is also useful and valuable in certain circumstances.

The top-down approach that was previously the only method applied in programme establishment is now combined with the bottom-up approach. The newly introduced PRA method (which is actually a combination of the top-down and bottom-up approached) has begun to be used widely in designing alternative activities in social forestry programmes.

However, although the PRA method is already being applied, the people still depend on other people (concessionaires). An increase in social welfare and environmental awareness might be achieved, but what about people's self-reliance should the concession holders lose their concession rights. There should be other institutions which would be responsible for continuing the programmes. For instance, after HPH-PMDH finishes (HPH no longer guides and supervises), it should be handed to another institution (local government) for the continuation and monitoring of the activities. Otherwise, there is possibility that the people will continue their former activities, and the objective of increasing the social welfare and self-reliance of the people will end in failure. There should therefore be a clear and proper coordination between all parties involved in programme establishment (Forestry Department, concessionaires, local government and other institutions). In addition, intensive extension and training should also be given to the concession holders who develop the programmes, so that they really understand the purpose of programme establishment (both technical and non- technical) before implementing the programme.

Finally, regular monitoring and evaluation of the implementation of various forms of social forestry programme has to be done to anticipate any problems and divergences during execution.

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DETECTING TROPICAL DEFORESTATION USING SATELLITE RADAR DATA

Belinda Arunarwati and Yousif Ali Hussin

Indonesia is the most richly tropical forested nation in Southeast Asia. Over most of the country, forest land use is regulated by a system of land assessment known as TGHK (*Tata Guna Hutan Kesepakatan*) or "consensus of forest land use". The key to wisely managing forest land and its resources is information. In the case of Indonesian deforestation, information is required not only about the rate and the extent of deforestation, but also about certain related factors such as the presence of deforestation in relation to TGHK classes, its location within each class of TGHK and its type. Data derived from remote sensors are increasingly being utilised as a data source in GIS. Conventional methods of remote sensing using optical systems have failed in some parts of Indonesia because of cloud cover. Radar, which is free from time and weather restrictions, may be a useful alternative source of remote sensing data in Indonesia.

Deforestation is expressed by the rate of change of forest cover area caused by the change of use of forest land from forest to non-forest. Several factors are directly responsible for the change in the forest, such as commercial logging, pasture, colonisation programmes or spontaneous migration, slash-and-burn agriculture, construction of highways, mining and hydro-electricity projects. Deforestation is mainly caused by expansion of agricultural activities and other land use practices, such as logging activity. It has been suggested that more than 80 percent of deforestation can be attributed to agricultural expansion. Logging, indirectly contributes to this major cause of deforestation by providing farmers with access through the construction of timber extraction roads.

The main objectives of this research were to investigate the potential of satellite radar data for detecting, differentiating and classifying deforestation in the forest concession area which has been selectively logged by PT Sylva Gama, Jambi, Central Sumatra, Indonesia. The following satellite images were used for this research project: Landsat-5 TM data of September 15, 1993, Spot XS data of March 21, 1993, ERS-1 images of October 17, 1993, June 6, 1994, and July 7, 1994, and JERS-1 of August 16, 1993. The research methodology is illustrated in Figure 2.

Figures 3 and 4 and Tables 1, 2 and 3 show a comparison between the ability of ERS and JERS satellite radar images to differentiate land and forest cover types, using both image classification and image visual interpretation.

Table 1 Differences between JERS-1 and ERS-1 radar images visual interpretation

JERS (L band)	**ERS (C band)**
Recognises 11 classes	Recognises 8 classes
Can separate old secondary forest and young secondary forest	Cannot separate old secondary forest and young secondary forest
Can distinguish rubber from forest	Cannot distinguish rubber from forest
Not good for distinguishing settlement	Good for distinguishing settlement
Can distinguish annual crops from agricultural land	Cannot distinguish the area of annual crops from agricultural land
Can detect clear cut	Can also detect clear cut
Plantation pattern of oil palm is not so clear	Plantation pattern of oil palm is more clear

Table 2 Comparison between two data sets of ERS and JERS images

First Data Sets (DS1) (ers1:red, ers2:green, ers3:blue)	**Second Data Sets (DS2) (jers:red, ers2:green, res3:blue)**
Recognises 6 classes	Recognises 7 classes
Cannot separate the forest into logged-over forest and secondary forest	Cannot separate the forest into logged-over forest and secondary forest
Cannot recognise oil palm, because mixed with the forest itself	Can see oil palm separately from forest, but cannot distinguish it from rubber
Can recognise the wet area	Can recognise the wet area
Clear cut can be seen, but bit difficult to detect	Clear cut easy to detect
Rice is more easy to detect	Rice can be seen, but is not so clear because mixed with water and wet area
Agriculture mixed with the trees (rubber and forest itself)	Agriculture mixed with the trees (rubber)
Cannot separate the forest stand from other perennial trees like rubber	Can separate the forest stand from other perennial trees like rubber

Table 3 The comparison of the result of both classification approaches

Some remarks	**Visual Interpretation**		**Digital Image Processing**	
	Single JERS	**Single ERS**	**Data sets with JERS and ERS**	**Data sets with ERS only**
Number of classes	11	8	7	6
Separates logged-over and secondary forest	yes	yes	no	no
Separates old and secondary forest	yes	no	no	no
Separates rubber from forest	yes	no	yes	no
Detects clear cut	yes	yes	yes	yes, but not so clear
Separates oil palm from forest	yes, but not so clear	yes	yes	no

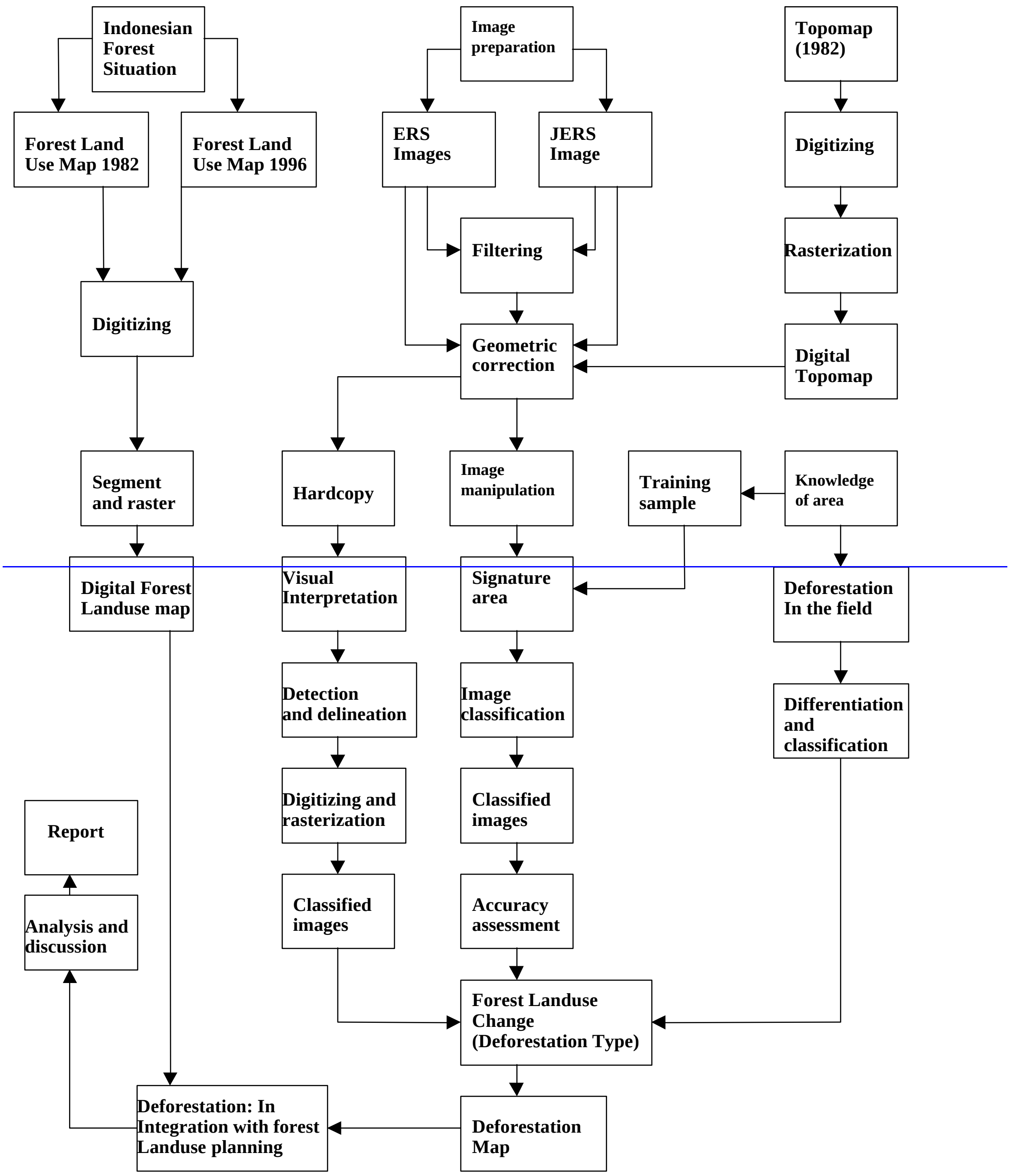

Figure 2 Research methodology

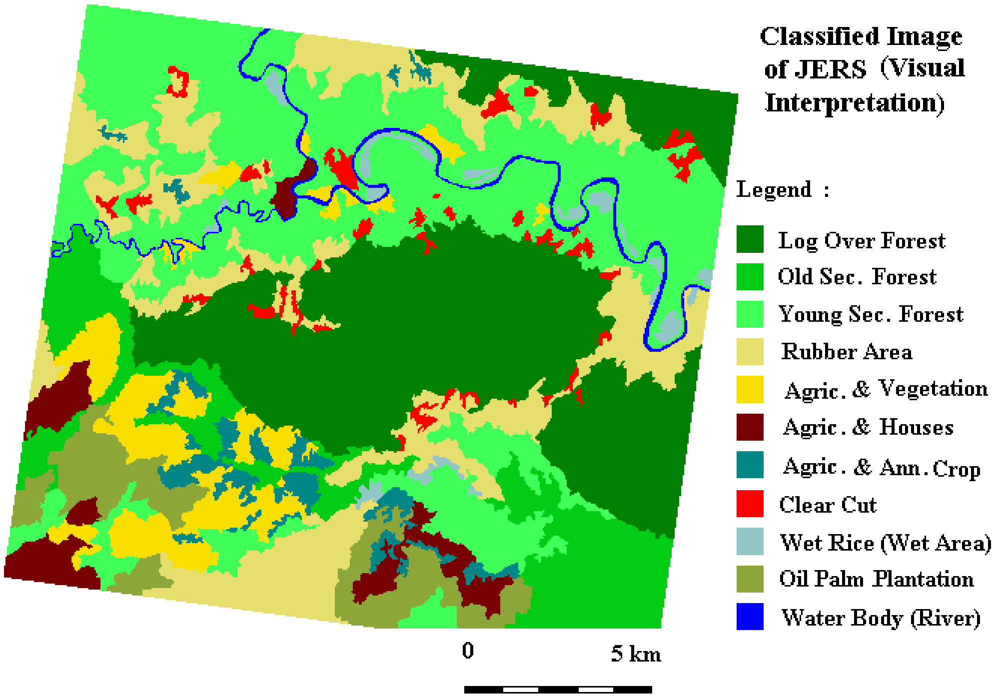

Figure 3 Classification results of JERS-1 Radar Image showing the deforestation in the study area

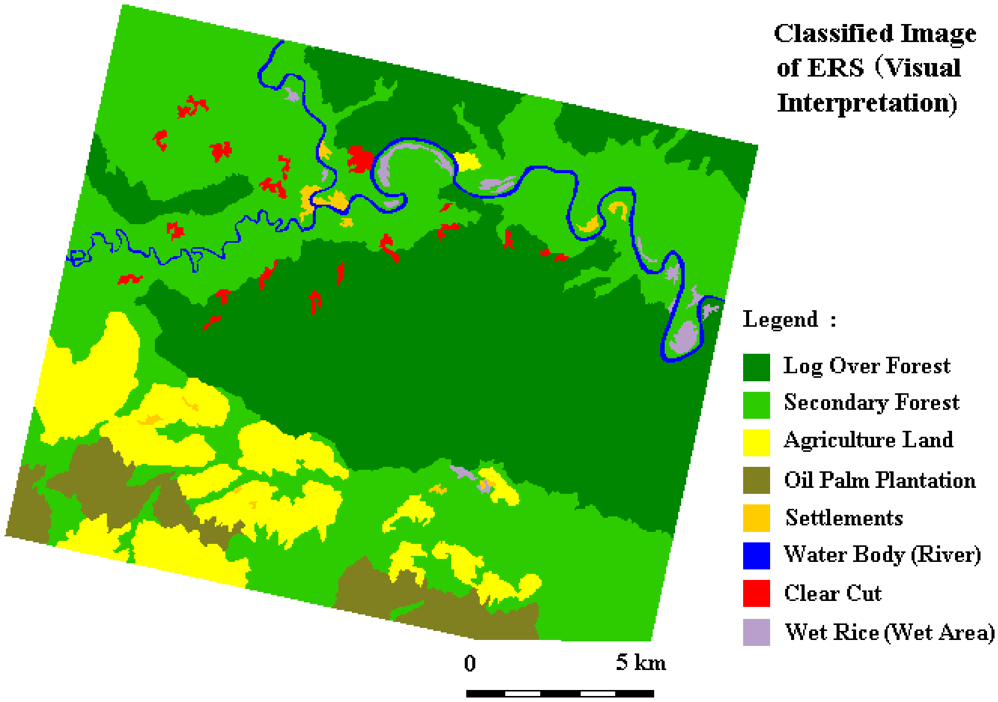

Figure 4 Classification Results of ERS-1 Radar Image showing the deforestation in the study area

MONITORING MANGROVE FORESTS USING REMOTE SENSING AND GIS

Mahfud M. Zuhair, Yousif Ali Hussin and Michael Weir

Mangrove forests form one of the primary coastal ecosystems in the tropical and subtropical regions of the world (Fig 1). They are biologically diverse and have therefore traditionally been utilised for food resources, firewood, charcoal, timber and other minor products. However, mangrove ecosystems are very sensitive and fragile. In recent years, the pressures of increasing population and the resulting expansion of agricultural land and industrial and urban development have caused the destruction of a significant proportion of the world's mangrove resource

* Because it is an archipelago, Indonesia has a large area of mangrove (4,250,000 ha are found around the four main islands). There are basically six categories of land use in the Indonesian mangrove areas: 1) forest reserves; 2) nature conservation; 3) protection forest; 4) production forest; 5) fish/shrimp ponds; and 6) salt production areas. Mangrove forests are traditionally a source of livelihood for the local population. The main problems of managing these resources therefore centre on delineating the area and resolving local community ownership issues. Significant areas of mangrove swamps in Indonesia and other regions of Southeast Asia have been developed to create ponds for the commercial production of fish and shrimps.

This poster describes research to compare three different radar satellite imaging systems (ERS-1, JERS-1, and Radarsat) and three types of optical satellite data (Landsat TM, MSS and Spot XS) for detecting and monitoring mangrove deforestation in the delta of the Mahakam River on the coast of East Kalimantan.

The research involved two main steps. In the first step, a broad classification of the general land cover, including mangroves was made (Fig 2). This indicated the best approach to dealing with the various types of imagery for detecting mangrove deforestation. The second step concentrated on the specific problem of detecting changes in the mangrove areas (Fig 3). It examined different approaches for monitoring the nature of the changes in order to produce maps showing the current and former conditions in the study area.

Three types of mangrove deforestation were found to occur in the study area:

1) deforestation caused by the establishment of agriculture and/or orchards;
2) deforestation caused by the establishment of oil pipeline networks;
3) deforestation caused by the establishment of shrimp ponds.

The mangrove forest area was seriously reduced between 1994 to 1996 in comparison with the period from 1982 to 1994 (Fig 4). It can be concluded from Figures 5 and 6 that the total mangrove area fell from 96,228 ha in 1982 to 91,827 ha in 1994, to 78,799 ha, in 1996,. The trends of these changes in the mangrove area are shown in Figure 6. It appears from these results, that about 13,028 ha (14.2% of the mangrove areas in 1994) disappeared in the period from 1994 to 1996, whereas only about 4,401 ha (4.6% of the 1982 area) disappeared between 1982 and 1994. The total mangrove area that disappeared between 1982 and 1996 was about 17,429 ha (18.1% since 1982).It may therefore be concluded that the mangrove forest area deteriorated predominantly between the period from 1994 to 1996.

Table 1 Classes detected in each image through supervised classification and visual interpretation

Landsat MSS	SPOT	Landsat TM	ERS-1	JERS-1	Radarsat
Broad-leaved	Broad-leaved	Broad-leaved	-	-	-
Nypa	*nypa*	*Nypa*	*nypa*	*nypa*	*nypa*
Water	water	Water	water	water	water
Ponds	dry pond	Fish pond	fish pond	fish pond	fish pond
-	orchard	Orchard	-	-	-
-	mixed	Mixed	mixed	mixed	mixed
Agriculture	agriculture	Agriculture	-	-	-
-	-	Clear-cut	clear cut	clear-cut	clear-cut
-	-	Half-cut	-	half-cut	half-cut
-	-	Swampy	-	-	
-	-	-	oil pipeline	oil pipeline	oil pipeline

Figure 1 Example of Mangrove Forest in the Delta of the Mahakam River, East Kalimantan, Indonesia

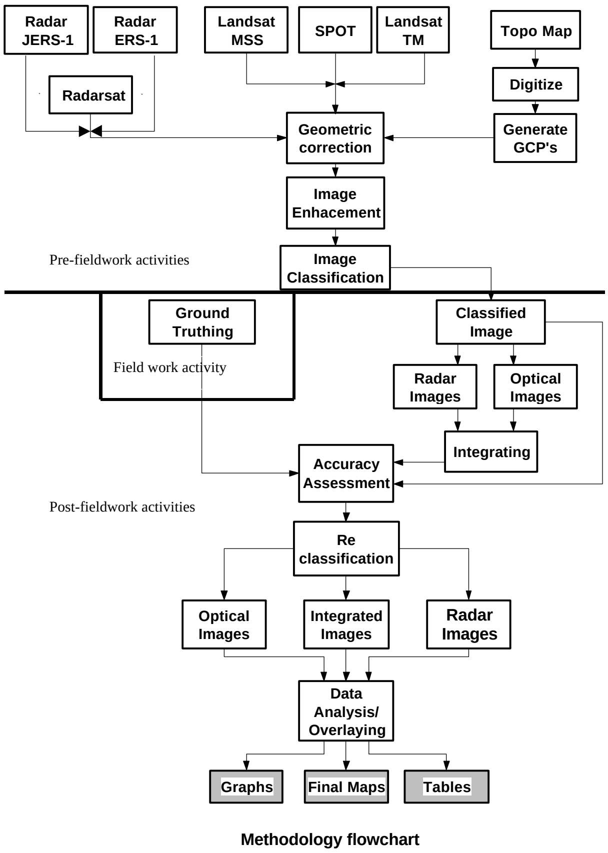

Figure 2 Methodology Flow chart (a)

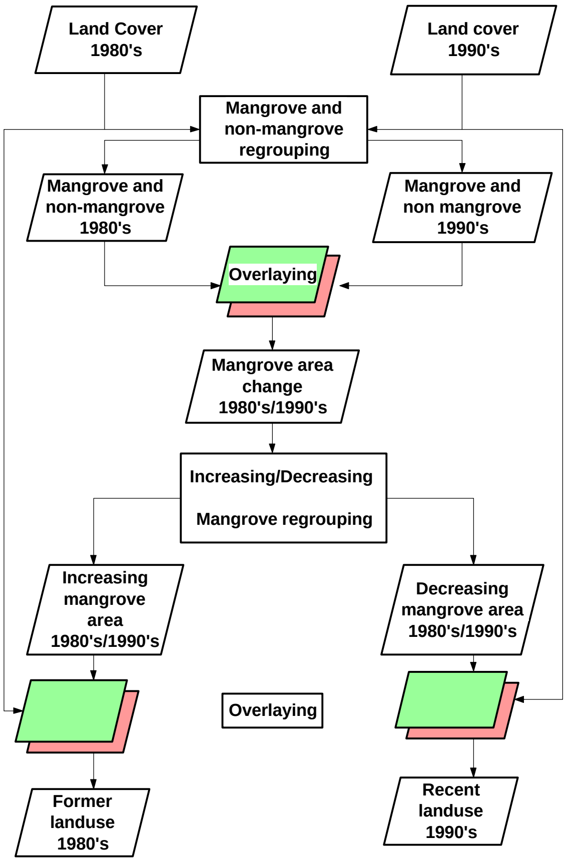

Figure 3 Methodology Flow chart (b)

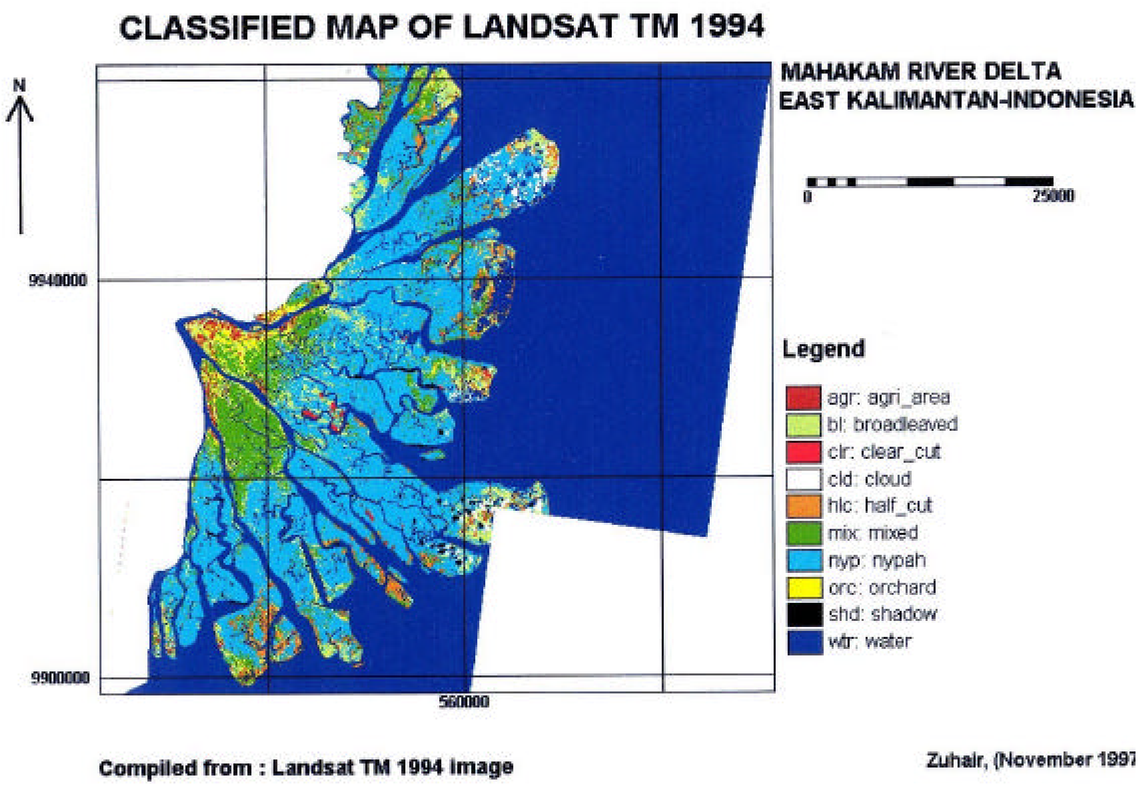

Figure 4 Example of the Remotely Sensed Image Classification

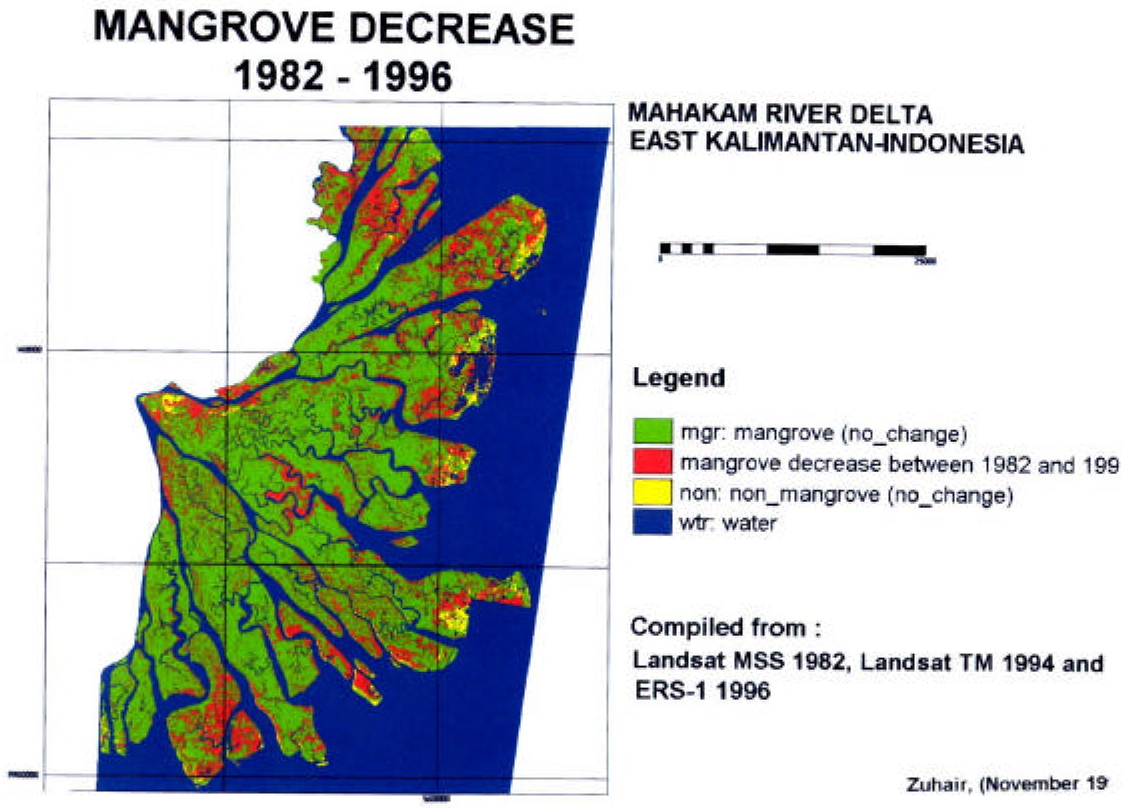

Figure 5 The Change Detection Analysis Results showing the Mangrove Deforestation

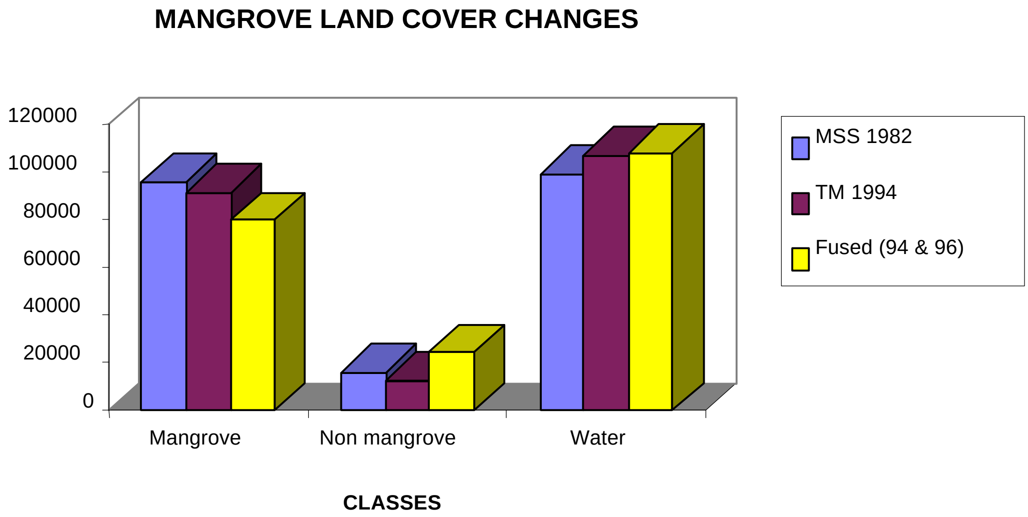

Figure 6 The area change as a result of Mangrove Deforestation.