FINAL REPORT

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Submitted by

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ENRICHMENT PLANTING WITH NATIVE SPECIES TO INCREASE THE ECONOMIC VALUE OF SELECTIVELY-LOGGED RAIN FOREST

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(with subcontracts to Harvard University)

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LIST OF ATTACHMENTS

Publications are bound separately. Due to the volume of material, copies of publications are provided only with the original copy of the report.

PUBLICATIONS AND REPORTS
supported by USAID/PSTC 9.249

Peart, D.R. 1996. Research in and near the Gunung Palung National Park, Indonesia, relevant to sustainable management of rain forest lands. *Tropical Biodiversity*, in press.

Schulze, P.C., M. Leighton and D.R. Peart. 1994. Enrichment planting in logged rain forest: integration of ecological and economic variables in experimental research. *Ecological Applications* 4:581-592.

Schulze, P.C., M. Leighton and D.R. Peart. 1992. Enrichment planting in logged rain forest: integrating ecological and economic variables in experimental research. Abstract of a paper presented at the second international meeting of the Society for Ecological economics, Stockholm, August, 1992.

Cannon, C., D.R. Peart, M. Leighton and K. Kartawinata. 1994. Structure of lowland rain forest after selective logging in West Kalimantan, Indonesia. *Forest Ecology and Management* 67:49-68.

Lawrence, D.C., M. Leighton and D. R. Peart. 1995. Availability and extraction of forest products in managed and primary forest around a Dayak village near Gunung Palung, Indonesia. *Conservation Biology* 9:76-88.

Lawrence, D.C., D.R. Peart and M. Leighton. The impact of shifting cultivation on a rain forest landscape in West Kalimantan: Spatial and temporal dynamics. Draft manuscript.

Alimudin, R.H. 1993. Population structure and regeneration of *Diallium wallichii* . Report to Indonesian Institute of Science.

Blate, G.O., David R. Peart and M. Leighton. Post dispersal predation on isolated seeds: a comparative study of 40 tree species in a Southeast Asian rain forest. Submitted to *Oecologia.*

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Setiadi, Y. 1993. A comparative study of abundance and distribution of seedling regeneration around parent trees of five I species in lowland rain forest. Report to the Indonesian Institute of Science.

Setiadi, Y., D.R. Peart, C.O. Webb and M. Leighton. In press. Abundance and spatial distribution of seedling recruitment around adult trees of five *Shorea* species. *Tropical Biodiversity.*

Tanuwijaya, S.M, R.H. Alimudin, D.R. Peart, C.O. Webb and M. Leighton. In press. Population structure and regeneration in two potentially valuable leguminous rain forest trees, Sindora *coriacea* and *Diallium wallichii,* in Gunung Palung National Park, Indonesia. *Tropical Biodiversity.*

Paoli, G., M. Leighton, D.R. Peart and I. Samsoedin. Economic ecology of gaharu (*Aquilaria malaccensis*) in Gunung Palung National Park, Indonesia: valuation of extraction and ecology of the residual population. In revision for *Conservation Biology.*

Blundell, A.G. In press. A species list of mammals for the Gunung Palung National Park, West Kalimantan, Indonesia. *Tropical Biodiversity.*

EXECUTIVE SUMMARY

Purpose of project: Our overall aims were (i) to assess the ecological and economic aspects of alternative land use practices and (ii) to contribute to the development of ecologically sound strategies for increasing the economic return and subsistence value of rain forests on poor soils in West Kalimantan.

Findings and contributions to development: The main factors leading to rain forest clearance by native Dayak villagers are apparently socioeconomic and political; the need for a cash crop (rubber) and the desire to "claim" land to stave off the perceived threat of conversion of natural forest to oil palm plantations. Currently, shifting cultivation by Dayak villagers affects a much smaller area of forest than either commercial logging or conversion to plantations. Commercial selective logging results in heavy damage to 70% of the rain forest canopy. Nevertheless, logged sites retain a high species diversity and contain patches of relatively undisturbed forest (especially in swampy sites), and contain residual resources for wildlife populations and local villagers. Some native tree species have high potential for enrichment planting. In particular, punah (genus *Tetramerista)* grows rapidly, has abundant natural regeneration and transplants extremely well in disturbed conditions. *Diallium* and *Sindora* also have potential for development for timber (both species) and for fruit (*Diallium*). Economic and ecological assessment of gaharu *(Aquilaria)*, the most valuable tree in the region, also indicates long-term management potential. Studies of spatial distribution, habitat preference and herbivore damage on dipterocarp seedlings provide information for ecologically sound management of dipterocarp timber populations. We suggest that there is great potential for the quantitative integration of rigorous ecological and economic assessments of forest management projects. We recommend this interdisciplinary approach to developing innovative methods of exploiting natural productivity sustainably and profitably. Our findings have been reported in 20 research papers, manuscripts and reports (see attachments), which have been distributed in Indonesia.

Training and collaboration: Training of Indonesians was a high priority. University faculty, thesis students and conservation (PHPA) professionals attended training courses in tropical tree dendrology and herbarium techniques. Four long term research students spent 4-6 months on site and published four papers and reports (attachments A), and several sarjana (thesis) students were jointly directed by us and by Indonesian faculty advisors. Collaborators included university faculty and scientists from the Ministry of Forestry and an NGO, who have authored or co-authored three papers and manuscripts.

1. RESEARCH OBJECTIVES

1.1. Broad goals

Our overall goals were (i) to assess the ecological and economic aspects of alternative land use practices and (ii) to contribute to the development of ecologically sound strategies for increasing the economic return and subsistence value of rain forests on poor soils in West Kalimantan. These aims address critical development issues in tropical rain forests in general, and in West Kalimantan in particular. We examined a range of land use intensities from heavily logged production forest to protected conservation areas. Our findings are applicable to secondary forest and to uncut rain forest managed by local villagers.

Unforeseen administrative constraints in Indonesia forced some changes to the proposal presented in the original work plan. These changes were described in our first annual report and in a letter to Mr. Jerry Bisson, of the Jakarta U.S.A.I.D. mission, attached to that report. The research goals listed above are more comprehensive than those in the initial proposal. Productivity has been very high and we believe accomplishments substantially exceed what was projected in the original proposal. The work reported here has formed the scientific basis for several active, current projects at and near the research site, including several PhD dissertations, ongoing Indonesian faculty research and a sustainable logging project recently funded by the Biodiversity Conservation Network (See Section 6).

1.2. Specific research objectives

(i) Development of a general approach to combining ecological and economic analysis for research on sustainable production
(ii) Assessment of effects of selective logging on rain forest structure
(iii) Assessment of the effects of selective logging on tree diversity
(iv) Evaluation of ecological and economic patterns of land use in and near selectively-logged rain forest
(v) Assessment of natural regeneration and enrichment planting potential of timber species in swamp and lowland forests

(vi) Analysis of ecological and economic aspects of the exploitation of the most valuable forest product in the region, gaharu

Additional objectives, related to the research objectives above, were:
(vii) Documentation of the flora and fauna of the Gunung Palung National Park
(viii) Contribution to development of an herbarium for rain forest trees in the province, in collaboration with the state university UNTAN, to facilitate tree identification and future basic and applied rain forest research;
(ix) Training of Indonesian students, scientists and agency employees in rain forest ecology and methods for applied ecological research.

Assistance with documentation of the flora and fauna, as part of our research in and around the park, was specifically requested by the Indonesian agency for nature conservation (PHPA) during the PSTC funded period. Students contributed to this documentation in addition to their regular research activities. Assistance with herbarium development was similarly requested buy faculty and administrators at UNTAN.

1.3 Other agencies and institutions involved

The work supported under the USAID/PSTC grant was facilitated by the USAID Jakarta Mission office, the Indonesian Institute of Science (LIPI), the Directorate of Nature Conservation (PHPA), the Ministry of Forestry, Universitas Tanjungpura at Pontianak (UNTAN), Dartmouth College and Harvard University. Additional funding was provided by Conservation, Food and Health (to Lawrence and Cannon) and the Merck Foundation (to Leighton). However, major funding during the period 1992-1995 was provided by USAID/PSTC.

2. METHODS AND RESULTS

Methods are not described in detail in this report, because of the wide range of research activities included. Methods are documented in detail in the reports and papers attached. Findings are summarized below, under the same research objectives listed in Section 1, above.

(i) Development of a general approach to combining ecological and economic analysis for research on sustainable production.

Traditionally, analyses of the economic aspects of development projects have been conducted separately from ecological analyses of productivity and sustainability. Yet, we suggest that a combined ecological and economic analysis is possible for many projects, and can be a very powerful approach to research and development. This integrated approach is especially important in the complex ecological environment of tropical forest lands, where continued economic and financial benefits are likely to depend heavily on ecological sustainability. We have demonstrated how research on innovative agroforestry systems, incorporating new species and management approaches, can benefit from preliminary financial appraisals that include both economic and ecological variables in quantitative cost-benefit models. (Schulze et al., 1994). Results from such models can provide vital information to speed the assessment and implementation of innovative approaches to sustainable management. This is important, because a rigorous evaluation of a proposed management system can be so time consuming that its potential contribution is never realized.

As a case study, we evaluated the ecological and economic potential of enrichment plantings of three native species of fruit-producing trees in commercially logged lowland forest in West Kalimantan. The model uses preliminary estimates of eight ecological parameters (including survival, growth rate and fruit production) and eleven economic parameters (including planting and harvesting costs and market prices) to predict net present value (NPV) over a variety of project durations and discount rates. Genera were chosen (i) for ecological complementarity, to use resources efficiently for production, and (ii) to produce fruit at times when commonly

harvested fruit species are not available. Sensitivity analyses indicated that all three species have potential for substantial positive NPV, and identified the critical variables affecting financial return.

(ii) Assessment of effects of selective logging on rain forest structure

Most rain forested land in Kalimantan is (or will be) subject to mechanized logging. There is little evidence to support claims that the official rotation periods are feasible or sustainable, but selectively logged forests do contain valuable resources. It is imperative to develop sound management strategies for logged forest. Management options for logged forest include continued commercial timber production relying mainly on natural regrowth of native species (the current management policy for production forest in Indonesia), forest management and harvesting by local villagers, or conversion to other uses, such as oil-palm plantations, rubber or agriculture. Critical information that is needed to inform the proper choice among these alternatives includes a thorough analysis of the effects of commercial, selective harvest on forest condition and of the resources remaining following logging.

To this end, we conducted a detailed analysis of forest structure following mechanized selective logging in a concession immediately to the north of the Gunung Palung National Park (Cannon et al. 1994). Most (76%) of the canopy of lowland forest was moderately to heavily disturbed by logging, which removed 43% of total pre-cut basal area. For dipterocarps, the dominant family of valuable timber trees, 62% of the pre-cut basal area was removed. Logging resulted in complex spatial mosaic of disturbance levels. Patches of swamp forest were relatively undisturbed, and contained residual resources of timber and non-timber species that could be harvested by local villagers. These patches of undisturbed forest represent potential habitat and food resources for wildlife populations. Thus, we suggest that in spite of the heavy disturbance resulting from commercial mechanized logging, secondary forests may still have high value, both for wildlife conservation and for the local inhabitants who know and depend upon the timber and non-timber species in nearby rain forest for subsistence and cash crops (Lawrence et al. 1995).

(iii) Assessment of the effects of selective logging on tree diversity

Specimens of several hundred species have been collected, dried, sent to herbaria, and matched against existing herbarium specimens in several major institutions in Europe, Indonesia and the USA. The final results of this laborious process are still not complete, but botanical specimens from logged forest sites have recently been morphotyped for diversity assessment (Cannon et al., in prep.). The levels of tree diversity are surprisingly high. From a conservation perspective, logged forests, in spite of tree mortality and extensive physical damage by heavy equipment, remain a substantial reservoir of plant biodiversity.

(iv) Evaluation of the ecological and economic patterns of land use in and near selectively-logged rain forest.

We examined the density and abundance of marketable forest products in primary forest and in the managed forest types (rubber gardens, fruit fallows and dry rice fallows) surrounding a Dayak village to the north of the national park. Villagers harvested four marketable tree products; timber, rubber, tengkawang (oil seed) and durian fruit (Lawrence et al. 1995). As expected, the proportion of managed forest types declined, and the proportions of logged and primary forest increased, with distance from the village. Although the total quantity of available durian and tengkawang in surrounding primary forest was greater than in the managed forest areas, villagers harvested these products only from managed forests. Managed forests were conveniently located and contained crops at a higher density per unit area than in primary forest.

As managed forests replace primary forest, the extent to which those managed forests may conserve biodiversity becomes an important question. In rubber plantations, which are the largest source of cash income, this potential appears to be limited, because tree diversity is negatively associated with the abundance of rubber trees (Lawrence, submitted). However, in fallows and fruit gardens, tree species diversity is much higher. In fact, over the samples collected, the range of species diversity measured for fallows, fruit gardens and primary forest overlapped (Lawrence, in press).

The rate of primary forest conversion by villagers has increased over the past five years (Lawrence et al, in prep.), due not to soil degradation (Kleinman, in press) or to population growth, but to the socio-economic and political environment faced by shifting cultivators. There is considerable economic pressure to convert primary forest (after a short period in rice cultivation) to rubber gardens. In addition, there is a perceived threat of large scale conversion of forest to oil palm plantations. Villagers believe that if they convert primary forest to rubber, this "improvement" will reduce the likelihood that government decision makers will approve a second conversion to oil palm.

In spite of the forces leading to continued forest destruction, the rate of conversion of primary forest by villagers is only one-third to one-quarter the rate of disturbance by commercial selective logging in the area. We discuss suggestions for alternative management and conservation approaches under "Implications for Stabilizing the Borders of Conservation Forest" in Lawrence et al (1995, attached).

(v) Assessment of regeneration and enrichment planting potential of timber species in swamp and lowland forests

To establish a firmer ecological basis for assessing the management and enrichment planting potential of native species, we examined the regeneration of several commercial and valuable non-commercial tree species. These included a peat swamp canopy tree, punah *(Tetramerista glabra).*, several species of *Shorea* in the dominant timber tree family, Dipterocarpaceae, and two leguminous canopy trees. Punah was the subject of the most intensive study; results are currently being applied in a new development project (see Section 6).

First, we summarize the ecology and management potential of punah, a peat swamp species with excellent timber characteristics. Although not harvested in commercial operations, because peat swamp is a difficult environment for heavy equipment, punah is prized locally for construction timber. We found that punah has a unique regeneration strategy that makes it ideal for

management by local communities. Although seedling establishment is rare, punah seedlings are common in the understory, because seedlings and saplings ramify extensively by vegetative reproduction. Juvenile plants are structurally unstable and become physically robust only in gap situations; in shade they collapse and ramify (Gavin et al., in prep. a). Their rapid and robust growth in gaps indicates excellent management potential in logged forest where gaps are abundant. Their natural response to gaps is probably related to the unusual abundance of canopy gaps in pet swamp forest, compared to other forest types of the world (Gavin et al, in press).

The abundant punah seedlings can easily be collected in the field (Gavin et al, in prep. b), and have excellent transplant performance (Gavin et al, in prep c). Typically, lowland forest contains patches of swamp forest, which implies that there are substantial, untapped resources of punah in selectively logged lowland forests. We suggest that these resources can be exploited efficiently by local communities and managed sustainably with enrichment planting.

For the dipterocarp species we examined (in the genus *Shorea)*, there was a heavy concentration of *Shorea* seedlings around parent trees. We conclude that reduced disturbance of the forest floor around felled trees during logging can substantially reduce damage to Shorea regeneration (Setiadi et al, in press). We also found that some species of *Shorea* regenerate well in gaps (Pribadi 1994) and that canopy disturbance following selective logging is very heterogeneous in space (Cannon et al., 1994). Thus, the focus of enrichment planting for gap-regenerating species should be in the disturbed areas of the canopy of logged forest.

Indonesian long-term trainees conducted research on two potentially valuable leguminous tree species, *Sindora coriacea* and *Diallium wallichii* (Tanuwijaya et al., in press). This research was designed as the first step in assessing their potential for exploitation and sustainable management. Both species have hard, durable timber and, as legumes, have nitrogen fixing potential. In addition, *Diallium* has edible fruits. Neither species is currently commercially exploited, so most trees should survive in residual stands following logging.

We found that both species occur commonly enough that they can easily be found in the habitat type in which they are most abundant. Both adult trees and seedlings can, with some practice, be identified in the field, even by workers with no prior taxonomic experience. Seedlings can be readily collected as wildings (for enrichment planting) by searching systematically around mature trees. With regard to timber resources, the naturally occurring basal areas (trees > 20 cm dbh) were 1.43 m^2/ha for *S. coriacea* and 0.79 m^2/ha for *D. wallichii*. Transplant experiments have recently been initiated for *S. coriacea*. We have found that seedlings can be transplanted with little short term mortality (Tanuwijaya, Peart and Webb, unpublished data).

(vi) Analysis of ecological and economic aspects of the exploitation of the most valuable forest product in the region, gaharu *(Aquilaria malaccensis)*

Gaharu is extraordinarily valuable because of the aromatic resin produced in response to fungal infection. This resin commands extremely high prices in the Middle East. Local market prices for gaharu ranged from US$ 1-500 per kg between 1982 and 1992, depending on the density, quality and aroma of the resin impregnating the wood. We found that ca. 50% of *Aquilaria* trees > 20cm DBH contained infected, harvestable gaharu wood. We assessed the population status of Aquilaria population inside the park. Because of its high value, gaharu has been exploited illegally (poached); 75% of trees > 20cm in the park have been cut. Nevertheless, residual juveniles > 2cm DBH occurred at four times the pre-harvest abundance trees > 20cm DBH. If poaching of *Aquilaria* were to cease, extinction of the population would appear unlikely. However, poaching in areas remote from the Cabang Panti research station (the only established human presence in the park) is likely to continue. However, seedlings and saplings remain abundant around adults; mean densities of juveniles ranged from 1-1.5 per 10 m^2 near both live and cut individuals > 20cm DBH. these densities were 100-150 times the mean density of juvenile *Aquilaria* in the forest. Because stumps and mature trees are relatively easy to locate by trained workers, seedlings can be easily gathered for enrichment planting purposes. Evidence for ecological potential for management of gaharu is therefore encouraging.

(vii) Documentation of the flora and fauna of the Gunung Palung National Park

We have produced a list of mammal species (Blundell, in press). A field guide to seedlings of the major family of timber trees, the dipterocarps (Webb and Curran, in press) and a list of bird species (Laman, in press) have also been completed recently , under separate funding.

3. IMPACT, RELEVANCE AND TECHNOLOGY TRANSFER

In this section, we refer to the research objectives listed in Sections 1 and 2.

(i) Development of a general approach to combining ecological and economic analysis for research on sustainable production

Or case study of enrichment planting of native species demonstrates that combined ecological and economic analyses are feasible, and illustrates the power of the approach. In the literature, there is continuing interest in the combination of ecological and economic research. International meetings on this topic have been held recently. However, there are at present few studies, other than ours. where these disciplines are effectively combined in field analyses. We strongly suggest that such integrated analyses be used more widely to assess the potential of alternative approaches to sustainable ecosystem management.

(ii) Assessment of effects of selective logging on rain forest structure

The published paper (Cannon et al., 1994) has already been well cited in the literature. It has generated some lively responses from scientists and Indonesian agency officials. The paper is the first to document the detailed impact of selective logging on rain forests of Kalimantan, based on a rigorous sampling methodology and statistical analysis. The research shows unequivocally the extent of physical damage by selective logging. We now know what ecological conditions prevail following logging. Because most of the accessible rain forest land in Indonesia is slated for selective logging, this

information is very useful. It been used in our case study of the integration of ecological and economic aspects of enrichment planting (see below) and in the development of a new sustainable logging project near the park boundaries (also described below). The research showed clearly that although damage is extensive, pockets of valuable resources remain (see above, Section 5 (i)). We expect the published analysis will be influential in the continuing debate over the management and conservation potential of logged forest.

(iii) Assessment of the effects of selective logging on tree diversity;

As noted in Section 2, this aspect of the research program is still in progress, because of the time required for biodiversity analyses. But we already know that the diversity of the heavily damaged selectively-logged forests remains high. Logged forests cover a much greater land area than preserves, and the proportion of rain forest area in logged forest will continue to increase. To the extend that logged forests are not further degraded (by burning and/or clearing), they will significantly augment the stores of biodiversity preserved in protected areas. (The trends toward conversion of rain forests and their causes are treated elsewhere in this report). Substantial tree species diversity is also maintained in fruit gardens and some of the fallow lands in shifting cultivation (Lawrence, in press). This information will allow us to begin mapping diversity in both disturbed and pristine habitats across landscapes including a mosaic of land use practices. This is necessary to provide a meaningful spatial inventory of biodiversity resources and to develop meaningful conservation strategies that take account of the realities of land use practices.

(iv) Evaluation of ecological and economic patterns of land use in and near selectively-logged rain forest

The low density of marketable fruits and seeds in primary forest has implications for conservation strategy for buffer zones around the park boundaries. Extractive reserves have been widely promoted in the literature as a means of stabilizing buffer zones around parks and preserves. However, our results show that limited extraction rights in buffer zone preserves (i.e. where non-destructive harvesting of fruits and seeds is allowed) may not

provide sufficient incentives to local villagers for the protection of buffer zone areas.

There has been much debate in the literature as to whether traditional systems of resource use by native peoples in rain forest areas are sustainable. However, our results for the Dayak villages we studied indicate that this debate, while interesting culturally and ecologically, is not the critical issue in the management and conservation of rain forest lands used by native peoples. The Dayak villagers to the north of Gunung Palung National Park, like virtually all inhabitants of remote areas, are influenced by social, economic an political forces in the developed world. Material and non-material products of developed societies are valued. In particular, villagers know that education for their children requires cash income and, eventually, travel to nor advanced schools than are available locally. The pressure to convert primary forest derives from the desire for increased cash income, and significant cash income cannot be generated from primary forest, given its low density of marketable products.

There are two clear implications for development. First, the actual dynamics of land use by indigenous people must be taken into account when projecting how patterns of land use will change over time. Even if traditional land use methods were stable and sustainable before contact with technological societies, the present reality is that the entire context of decision making at the individual, family and community levels changes has been greatly modified, compared to pre-industrial times. The consequence is net conversion of primary forest to managed forest land (particularly rubber plantations) even for villages without appreciable population growth.

The second implication is perhaps more important and urgent, and stems from the first. If our goal is to influence land use practices positively by developing and implementing enlightened policies, these policies must certainly take into account the socioeconomic realities faced by local people. In particular, the development of buffer zones around parks and preserves is likely to be successful only if there is adequate motivation, policing or both. Although some monitoring and policing is always necessary, we suggest that buffer zone systems will fail in the long run if local people do not value

them. The following guidelines for land use policy in buffer zones surrounding the park follow directly from the results of our research:

(a) Local people should have adequate area for managed forest (rubber, fruit gardens, fallows). These provide most of their subsistence and virtually all cash income.

(b) At current population levels, there is sufficient area in forest that villagers do not need to convert most of the existing forested land to managed forest types.

(c) If rain forest is to be maintained in buffer zones, in addition to the managed forest types, sufficient incentives to maintain rain forest ecosystems must exist. Therefore, additional benefits beyond the harvesting of non-timber forest products from rain forest should be provided to local people.

(d) We suggest that limited, sustainable extraction of timber would provide sufficient incentives to maintain rain forest. If it is not available from the local forests, timber must be purchased from villagers' limited cash income. However, if can be made available in excess of village needs, timber can be marketed for cash income. We estimate that there is sufficient land around the borders of the park, relative to population level, so that sustainable harvest of timber in excess of village needs is possible. To this purpose, we have begun implementing a sustainable logging project in the Semanjak area, with approval form the Ministry of Forestry for designation of a community forestry area. Extraction and enrichment planting are to be managed by a local cooperative. Establishment of this project has been funded by the Biodiversity Conservation Network, based on results of PSTC research.

(e) Limited, sustainable timber extraction without heavy equipment could be carried out in either pristine forest or forest that has already been commercially logged. In selectively logged lowland forest, substantial areas of uncut swamp forest remain, containing valuable timber resources.

(f) Low impact logging by local villagers is likely to maintain a forest ecosystem with at least the level of biodiversity that remains following

commercial logging. These areas have high potential as buffer zones. Providing further degradation by cutting and burning does not occur, the tree diversity of selectively logged forest is high, with high potential for wildlife habitat for many species.

are to be influenced by
If the current trends in land use lead to undesirable and (eventually) unproductive

(v) Assessment of regeneration and enrichment planting potential of timber species in swamp and lowland forests

We recommend punah as a focal species for local community forestry projects in swamp forest, based on its excellent regeneration and enrichment planting attributes. Furthermore, these benefits to rural householders can be substantially realized without prejudicing the commercial interests of mechanized logging activities in logging concessions. These recommendations are already being implemented in a community forestry project (see below).

We have decided to make swamp forests the focus for our own efforts at implementation based on the findings of PSTC-funded research. However, the results from lowland dry forest will also be useful in forest management. Our findings suggest that the two leguminous trees (*Sindora* and *Diallium*) may have management potential, especially for local village dwellers, and further experiments on enrichment planting are justified. The results on the dipterocarp species provide practical information for current efforts in the Ministry of Forestry to improve silvicultural practices for commercial timber species. The results can also be incorporated into local community forestry projects to manage both major commercial species (dipterocarps) and other native, non-commercial species like *Diallium* and *Sindora* .

(vi) Analysis of ecological and economic aspects of the exploitation of the most valuable forest product in the region, gaharu *(Aquilaria malaccensis).*

The total net financial value (NFV) to village collectors of gaharu wood in the ca. 9,200 diseased trees in the park in 1988 was estimated at US$ 727,000; villagers harvested 92% of these trees, generating $667,000 in income. The average net financial return to collectors was US$5.25, three times the village wage for unskilled or semi-skilled labor. This generated significant economic and social benefits locally, as income was widely distributed among households, including the poorer ones. Because the harvested gaharu mad up a tiny fraction of the trees in the forest (the density of cut trees was only 0.08-0.28 per ha), disturbance to the forest by harvesting was minimal. We conclude from our ecological and economic analyses that gaharu merits further study for the ecological engineering of buffer zone forests to produce high value, low density products.

(vii) Documentation of the flora and fauna of the Gunung Palung National Park

The Indonesian conservation agency (PHPA) will use the information on mammals and birds to justify support for staff to patrol and monitor the park. The key to dipterocarp seedlings will facilitate research on dipterocarps in the park and in logged areas outside the park boundaries.

4. PROJECT ACTIVITIES/OUTPUTS

4.1 Meetings

As part of the PSTC-funded project, we funded two symposia in Indonesia, and presented a paper at one international meeting (Schulze et al., 1992).

4.1.1 *Symposium in Pontianak, January, 1992*

This was a one day event held at the conference center of the Universitas Tanjungpura (UNTAN) in Pontianak. The symposium was devoted to the research project at Cabang Panti, and was designed to acquaint researchers,

administrators and agency staff with the scope and purpose of our research programs in and around the park. UNTAN faculty and administrators requested the symposium, providing an excellent opportunity for communication. Attendees: University faculty and students, representatives of NGOs, Ministry of Forestry (research and production forestry staff), PHPA (nature conservation) and BAPPEDA (land planning). Approximately 40 persons attended the meeting.
The agenda included:

Opening remarks by the University Rector
Welcome by the Chair of Forestry
Presentation by M. Leighton of basic research programs and conservation implications
Questions and Discussion
Lunch
Presentation by D. Peart of applied aspects, focusing on PSTC funded research
Questions and Discussion

4.1.2 *Symposium in Bogor, March 1995*

This was also a one day event, also focusing entirely on our research at Cabang Panti, Gunung Palung. However, this meeting consisted of a series of presented papers by western and Indonesian researchers at the site, focusing on completed work rather than research plans. Attendees: faculty from national universities in Bogor and Jakarta, from the national herbarium (Herbarium Bogoriense), the Center for Research and Development in Biology (LIPI; PPPB), the national office of nature conservation (PHPA) and the Ministry of Forestry. The event was hosted by the Indonesian Institute of Science (LIPI).

Agenda:
Opening remarks by Dr. Arie Budiman (LIPI)
Comments By Dr. Dedy Darnaedy (LIPI)
Overview by M. Leighton
Presentations by researchers (including Leighton, Peart, Budhi)
Discussion led by Dr. Budiman.

Most presentations and the discussion focused on the potential applications of research to management and conservation issues, and additional research needed to address critical management and conservation needs. It was decided at the meeting to produce a special issues of the international journal *Tropical Biodiversity*, devoted to the Gunung Palung project. This issue is due to be published in the first half of 1996 and will include several papers on research funded by PSTC (see list of publications).

4.1.3 *International meeting*

We presented a paper at the second meeting of the International Society for Ecological Economics at Stockholm, Sweden in August, 1992 (Schulze et al., 1992). The paper generated lively discussion at the meeting.

4.2 Training

4.2.1 *Long term (six month) research traineeships*

Four advanced students were chosen from a national applicant pool by the Indonesian Institute of Science (LIPI). These students, R. Hasan Alimudin, Saimun Tanuwijaya, Cahyo Pribadi and Yosef Setiadi, completed substantial research projects that are reported in manuscripts and reports as senior authors in English. Two of these are in press in the international journal *Tropical Biodiversity* (Setiadi et al, in press; Tanuwijaya et al, in press). All students were scheduled over the same six month period. Mr. Geoffrey Blate, with qualifications in ecological research, teaching and Indonesian language, was the full time field staff person charged with training. Blate organized sessions in research methods, tropical dendrology, field safety, statistical analysis and computing methods at the beginning of the long term program, with further training as necessary on a continuing basis.

Principal investigators Peart and Leighton were at the station for the first part of these projects, to establish the research plans and experimental designs. In addition, the long term trainees had daily contact and advice from several

western graduate students and research assistants, as well as the assistance of six experienced Indonesian field staff.

4.2.2 *Medium-term Indonesian research students*

These students conducted thesis research administered by Indonesian universities and faculty. Of the thesis projects completed with PSTC assistance, all except one were from the regional university, UNTAN. We entered into an agreement with UNTAN to support thesis research at the Cabang Panti Research Station, Gunung Palung. We and our staff provided scientific advice to faculty and students, as well as accommodation and research equipment a the site.

4.2.3 *Specific technical training*

We provided transport and accommodation for six faculty and agency professionals, and practical, hands-on instruction in tropical tree taxonomy and collection methods. Indonesian students, scientists and agency employees were instructed in the basics of rain forest ecology and in methods for applied ecological research.

During their stay at the research station, long term students were trained in the following areas:

(a) research methods, including framing of hypotheses and sampling design
(b) tropical dendrology,
(c) field safety,
(d) statistical analysis,
(e) computing methods, and
(f) scientific writing.

Short term students were trained in basic methods at their home institution. At the research site, our training efforts were focused on

(a) basic instruction on the trail system, rain forest habitats and use of equipment and facilities, and
(b) assistance with sampling/experimental design
(c) assistance with analyses and interpretation of results

4.2.4 *Comments and recommendations*

Training in the writing of manuscripts and reports was a major effort for us and our staff. The ability to write technical papers, even apart from command of English, has been a major limitation to the majority of Indonesian scientists, who do not have the benefit of training in a western university. Assisting Indonesian students with scientific writing was far more time consuming than the alternative of writing the papers ourselves. However, we believe this aspect of training is essential in developing scientific and technical expertise within Indonesia.

We suggest that investment in within-country, on-site training of this kind can be very effective in increasing host-country scientific expertise. Clearly it cannot replace foreign training at the graduate level. But foreign graduate training programs are very expensive and can serve only a limited number of students. In-country training can be more widely available to nationals, providing long term researchers are willing to mentor the host-country students. This type of training has the benefits of close contact with active researchers and a more immediate focus on research methods and questions relevant to host-country development.

Students and scientists trained at Cabang Panti have found employment in conservation and development of natural resources. Collaborating faculty and student trainees have, for example, been hired as consultants on the USAID Natural Resources Management project in West Kalimantan. One collaborating faculty member, Setia Budhi, whose graduate training was limited to the MS degree, has been successful in attracting funds for the PhD degree in the USA, based mainly on his collaborative research.

4.3 Contribution to herbarium development

An active, comprehensive, expertly managed herbarium is sorely needed in West Kalimantan. Plant diversity (especially rain forest trees) is extremely high, yet knowledge of the flora is poor amongst scientists and government agency staff responsible for management of these tropical ecosystems and

their plant resources. We have promoted the development of an herbarium at UNTAN, the university in the capital of Pontianak. The purpose of the herbarium is to facilitate tree identification, education and future basic and applied rain forest research. We have contributed to this purpose in three ways:

(a) Indonesian faculty and staff attended a training camp at the Cabang Panti research station, with field instruction in tropical tree taxonomy and identification.

(b) We provided training in herbarium methods (specimen preparation, drying, mounting and storage), also on-site at the research station.

(c) We directed the collection of specimens in the field and provided additional specimens to initiate the collections. Trained faculty could now supervise student collections to expand the herbarium collections.

Thus, PSTC funding supported training, increased awareness and facilitation of collecting access to an area (Gunung Palung National Park) that contains the widest range of undisturbed natural habitats in west Kalimantan.

The herbarium is one of the first steps in addressing the widespread ignorance of local biological resources. Realistically, it is likely that continuing training and technical support (beyond the PSTC funding period), together with funding for herbarium facilities, will be needed to make the UNTAN herbarium effective as a center for the inventory and study of plant biodiversity in West Kalimantan.

4.4. Collaboration with Indonesian scientists and agencies.

Our main focus on strengthening of Indonesian Institutions was on the state university, Universitas Tanjungpura (UNTAN), which is vital for scientific development and applications throughout the large state of west Kalimantan. Dr. Herujono, Chair of forestry at UNTAN, has been our main contact on administrative matters, while Setia Budhi, the most active forest ecologist,

has consulted with us on ways to increase the research and training opportunities for students and faculty. Other important collaborations have been with the Indonesian Institute of Science (LIPI) and the Ministry of Forestry.

The following is a summary of collaborations:

(a) Dr. Soetikno Wirjoatmodjo and Dr. Dedy Darnaedy, of the Indonesian Institute of Science (LIPI), our official Indonesian sponsoring organization, have been the main coordinators of our collaborations with other Indonesian institutions.

(b) Dr. Herujono Hadisuparto, Chair of Forestry at UNTAN, has collaborated with us on administrative arrangements for his staff, and on development of the Herbarium.

(c) Dr. Kuswata Kartawinata, formerly UNESCO Indonesia and presently with the McArthur Foundation, is co-author on one manuscript in press (Cannon et al., 1994). Dr. Kuswata has consulted with and advised us on various aspects of research in Indonesia and relations with Indonesian institutions.

(d) Ir. Ismayadi Samsoedin (agency for research and Development, Ministry of Forestry) collaborated on the gaharu project (Paoli et al, in revision).

(e) Two UNTAN faculty, Setia Budhi and Icksan, completed a research project on the population structure and regeneration of Bornean ironwood *(Eusideroxylon zwageri)*. The data are now being analyzed (Budhi et al, in prep.).

4.5 Publications

A total of 20 articles have been supported in whole or in part by the PSTC grant. PSTC was the major source of funding during the period. The 20 articles comprise 7 that have been accepted for publication in international journals (3 papers in print and 4 in press), 2 submitted papers, 6 manuscripts in preparation (3 of which are included with this report), 4 reports to the

Indonesian Science Institute (LIPI) and one abstract of a paper presented at an international meeting.

An overview paper is in preparation to draw together the many findings relevant to sustainable harvest and management:

Peart, D.R. Research in and near the Gunung Palung National Park, Indonesia, relevant to sustainable management of rain forest lands. Draft manuscript.

Articles on more specific research results are listed below under the appropriate research objectives (as listed in Section 1). Copies of articles marked with an asterisk are included with this report.

(i) Development of a general approach to combining ecological and economic analysis for research on sustainable production

*Schulze, P.C., M. Leighton and D.R. Peart. 1994. Enrichment planting in logged rain forest: integration of ecological and economic variables in experimental research. *Ecological Applications* 4:581-592.

*Schulze, P.C., M. Leighton and D.R. Peart. 1992. Enrichment planting in logged rain forest: integrating ecological and economic variables in experimental research. Abstract of a paper presented at the second international meeting of the Society for Ecological economics, Stockholm, August, 1992.

(ii) Assessment of effects of selective logging on rain forest structure

*Cannon, C., D.R. Peart, M. Leighton and K. Kartawinata. 1994. Structure of lowland rain forest after selective logging in West Kalimantan, Indonesia. *Forest Ecology and Management* 67:49-68.

(iii) Assessment of the effects of selective logging on tree diversity

Cannon, C.H, D.R. Peart and M. Leighton. Tree species diversity in logged forest in West Kalimantan, Indonesia. Draft manuscript.

(iv) Evaluation of ecological and economic patterns of land use in and near selectively-logged rain forest

*Lawrence, D.C., M. Leighton and D. R. Peart. 1995. Availability and extraction of forest products in managed and primary forest around a Dayak village near Gunung Palung, Indonesia. *Conservation Biology* 9:76-88.

*Lawrence, D.C., D.R. Peart and M. Leighton. The impact of shifting cultivation on a rain forest landscape in West Kalimantan: Spatial and temporal dynamics. Draft manuscript.

(v) Assessment of natural regeneration and enrichment planting potential of timber species in swamp and lowland forests

*Alimudin, R.H. 1993. Population structure and regeneration of *Diallium wallichii* . Report to Indonesian Institute of Science.

*Blate, G.O., David R. Peart and M. Leighton. Post dispersal predation on isolated seeds: a comparative study of 40 tree species in a Southeast Asian rain forest. Submitted to *Oecologia.*

Budhi, S., D.R. Peart and C. O. Webb. Population status of Bornean ironwood in Gunung Palung National Park. Draft manuscript.

*Gavin, D.G. D.R. Peart and M. Leighton. In press. Canopy structure of peat swamp forest in West Kalimantan, Indonesia. *Tropical Biodiversity.*

*Gavin, D.G., D.R. Peart and M. Leighton. Potential for enrichment planting of punah (*Tetramerista glabra),* a peat swamp timber tree. Draft manuscript.

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*Pribadi C. 1993. A comparison of regeneration between gap and understory for six species of *Shorea* in lowland rain forest at Gunung Palung National Park, West Kalimantan. Report to the Indonesian Institute of Science.

*Saimun, M.T. 1993. Population structure and regeneration in *Sindora coriacea.* Report to the Indonesian Institute of Science.

*Setiadi, Y. 1993. A comparative study of abundance and distribution of seedling regeneration around parent trees of five I species in lowland rain forest. Report to the Indonesian Institute of Science.

*Setiadi, Y., D.R. Peart, C.O. Webb and M. Leighton. In press. Abundance and spatial distribution of seedling recruitment around adult trees of five *Shorea* species. *Tropical Biodiversity.*

*Tanuwijaya, S.M, R.H. Alimudin, D.R. Peart, C.O. Webb and M. Leighton. In press. Population structure and regeneration in two potentially valuable leguminous rain forest trees, Sindora *coriacea* and *Diallium wallichii,* in Gunung Palung National Park, Indonesia. *Tropical Biodiversity.*

(vi) Analysis of ecological and economic aspects of the exploitation of the most valuable forest product in the region, gaharu

*Paoli, G., M. Leighton, D.R. Peart and I. Samsoedin. Economic ecology of gaharu (*Aquilaria malaccensis*) in Gunung Palung National Park, Indonesia: valuation of extraction and ecology of the residual population. In revision for *Conservation Biology.*

(vii) Documentation of the flora and fauna of the Gunung Palung National Park

*Blundell, A.G. In press. A species list of mammals for the Gunung Palung National Park, West Kalimantan, Indonesia. *Tropical Biodiversity.*

5. PROJECT PRODUCTIVITY

Productivity of the research funded by PSTC has exceeded all our expectations. We were fortunate in having a number of highly motivated students with excellent technical skills, who produced high quality work. The research outputs per dollar of research support were, we believe, very high.

A greater diversity of research was carried out than was originally proposed in our funding proposal. As indicated in detail in earlier annual reports, a misunderstanding between BAPPEDA (the state land planning agency) and the Ministry of Forestry resulted in long delays in approval of enrichment planting trials in logged forest operated by concessionaires. Research efforts were immediately redirected to (i) the effects of land use practices on rain forest systems and (ii) the potential for management by local villagers of valuable native tree species, for timber and non-timber products.

The summary of research findings (Section 2) and their implications (Section 3), the list of publications (Section 4.5) and the two symposia organized in Indonesia (Section 4.1) document the high productivity of this project.

6. CURRENT AND FUTURE WORK

The research supported by USAID/PSTC has been extremely effective in generating further research activity.

6.1 Graduate research

Current graduate theses addressing issues of conservation and management include:

Deborah Lawrence (Duke University). Species diversity in a landscape under shifting cultivation.

Peter Kleinman (Cornell University). Assessment of sustainability of land use practices based on soil nutrient dynamics.

Campbell O. Webb (Dartmouth College). Tree diversity and the ecological mechanisms responsible for its maintenance in rain forest.

Gary Paoli (University of Michigan). Economics and ecology of exploitation of rain forest trees (topic still to be finalized).

Additional thesis projects addressing basic research questions on primate ecology and forest ecology are also in progress.

6.2 Sustainable logging project

A development project is currently under way in swamp forest near the border of the park. This project stemmed directly from PSTC funded research.

The objectives of the project are to:

(i) harvest forest products sustainably using low impact techniques
(ii) maximize financial benefits to local communities
(iii) stabilize land use in a buffer zone around the national park
(iv) preserve wildlife habitat and species diversity.

The design of the project was based on PSTC funded research on:

(i) methods for joint ecological/economic evaluation of projects
(ii) land use practices and their ecological implications
(iii) enrichment planting potential of native species.

This projected is directed by M. Leighton, and is conducted with the approval and collaboration of the Ministry of Forestry. Implementation in the local community assisted by an Indonesian NGO. Villagers form Semanjak, just outside the park boundaries, will harvest trees from swamp forest and process them locally at their own sawmill. The swamp forest allocated to this community forestry project has been exploited somewhat prior to this project, but is mostly intact and contains valuable resources of timber trees, including the excellent timber species, punah *(Tetramerista glabra)*. Punah has been the subject to intensive PSTC-funded research (Gavin et al., in prep a,b). We found that punah is ideally suited to enrichment planting following selective cutting in swamp forest (Sections 2 and 3). Our ecological and economic assessments, based on field surveys of the area (Leighton, unpublished data), experiments with punah (Gavin et al in prep, b), and joint financial/ecological analyses (sensu Schulze et al., 1994) indicate excellent potential for long term, sustainable management of the area.

Funding for the initial stages of the project is from the Biodiversity Conservation Network. The planning stage has been completed, and the first year of implementation is now in progress.

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