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UTILIZING GRADUATE RESEARCH TO TEACH TROPICAL RESOURCE CONSERVATION: WE GRADUATE STUDENTS CAN MAKE A DIFFERENCE.

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As I conduct my doctoral field research--studying factors that contribute to plant species diversity in Sarawak, Malaysia--I am teaching and learning with local students and people about the wonders and complexities of their forests. I am able to do this through a student internship program I have developed with Dr. Hamsawi Sani, Professor of Silviculture at the former Bintulu campus of the University of Agriculture, Malaysia. The internship program was designed to *provide Malaysian forestry students with the opportunity to* develop forest ecology research skills in a field setting.

Utilizing my own and others' research at the Lambir Hills National Park Long Term Ecological Research Site (6° 20'N, 116° E) (Watson 1985, CTFS 1993), we are exposing the students to ecological processes relevant to sustainable management of these tropical rain forests. This interaction is not only a rewarding part of graduate research but also has great potential to substantially contribute to the future conservation and management of tropical resources.

WHY DEVELOP AN INTERNSHIP PROGRAM?

As tropical countries develop, the need for natural resource managers and policy makers will increase exponentially. It has often been stated that developing countries simply do not have personnel with technical expertise, or that those that have the skills are in administrative positions that prevent them from applying their expertise. If these statements are true, a larger pool of resource managers needs to be trained.

At the international level, training courses, such as those offered by the Organization for Tropical Studies, touch a very small and select group of students--students that may not end *up in positions affecting the resources of their country.* Funding by international and US agencies does not require any formal training of students at the college level, nor does it require investigators to support education of local students. Perhaps, because of time constraints on university faculty, local educational support would not and could not be an appropriate grant stipulation. Graduate students, however, often have more time than money, and can "afford" to work with local students, sharing the excitement of new discoveries in the research process. Graduate student research might provide a more feasible avenue for educational exchange between students. Through local university faculty, we can *tap into the desire of local students to acquire field experience* in forestry/ecological research. One weekend, one week, or several months can provide students with experiences they would not otherwise receive. *(continued on p.2)*

Contents

Articles

Student Research

Educational internship programs will enhance cultural exchange and break down barriers that develop from our ignorance of others' cultures and knowledge. Ultimately, they may provide healthy interactions that can be cultivated throughout our careers.

PREVIOUS INTERNSHIP SUCCESS AND FUNDING

The idea of a student internship program came from my experience working with Indonesian students who were involved in Dr. Mark Leighton's (Harvard University) student scholarship program at the Cabang Panti research site in West Kalimantan, Indonesia between 1988 - 1990. As a research assistant for Dr. Leighton, and later while conducting my Masters research, I worked with Indonesian students as they developed and completed research projects (Palmiotto 1991). Dr. Leighton's program relies on US students to work with and assist the Indonesian students. Such interactions have been extremely successful for everyone involved. I was able to assist the Indonesian students during my Masters field research and now have been able to develop a student internship program at Lambir with support from the Conservation, Food and Health Foundation Inc., Cambridge, Massachusetts, USA and the Yale University Tropical Resources Institute, New Haven, Connecticut, USA.

INTERNSHIP OPPORTUNITIES IN LAMBIR

I visited Dr. Hamsawi at the Bintulu campus in June 1993 to discuss the internship program. With great enthusiasm and support Dr. Hamsawi sent four students to Lambir in September 1993 and two more students in November 1993, each for one week. The students assisted me in mapping tree fall gaps--where we discussed aspects of gap dynamics--and in data collection on experimental seedlings--where we discussed site characteristics, regeneration, and physiology as they relate to forest succession and diversity.

The most rewarding event of this past year's program came in October when Dr. Hamsawi and I conducted a silviculture/ecology field trip for 73 students, faculty and staff from the Bintulu campus. During the two day field trip we used current research at Lambir as a teaching aid to provide an ecological basis for their silvicultural studies. We covered topics such as sampling design, ecosystem management, regeneration strategies, and disturbance. Dr. James LaFrankie from the Center for Tropical Forest Science, Singapore, provided insights into the realm of plant systematics and botany and the value of identifying the 100,000 or more specimens from the 52 ha plot. Teruyoshi Nagamitsu, a Ph.D. Candidate from Kyoto University, Japan, explained the pollination ecology of the forests, and Mr. Rapi Rahman from the Sarawak Forest Department presented a phenological picture of the forest from the top of a 30 m tree tower. In the evening, the class was separated into groups, and each group addressed a set of questions and presented their impressions of what they learned during the day. The field trip exposed the entire class to ecological research at Lambir and to the ideas of ecosystems, sustainability, conservation, and interactions that, in the words of Dr. Hamsawi, "allowed them to understand the aspects of [their] silviculture class better."

Interns working in Lambir Hills National Park, Sarawak, Malaysia.

FUTURE OF THE INTERNSHIP PROGRAM

Dr. Hamsawi and I are planning similar activities for 1994. We hope to support two students for two months and six students for one to two week periods during the academic year. The Bintulu campus will close in May of 1994, but connections with Dr. Hamsawi, who will move to the new state university, University Malaysia Sarawak (UMS), are strong. At UMS the curriculum focuses on biodiversity and may produce students interested in pursuing ecology as a career. Internships at Lambir could prove invaluable to students who seek field experience in ecological research.

SUMMARY

Cross-cultural exchanges in an educational setting are full of positive energy. These interactions provide the atmosphere where learning is synergistic, each individual learning more from each other than they could on their own. Such interactions contribute more than a piece of paper to our graduate education: they provide an opportunity to give back, to broaden the perspectives of all those involved.

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THE UNPAVED ROAD FROM THE RIO SUMMIT: BRAZILIAN AMAZON'S EXTRACTIVE RESERVES

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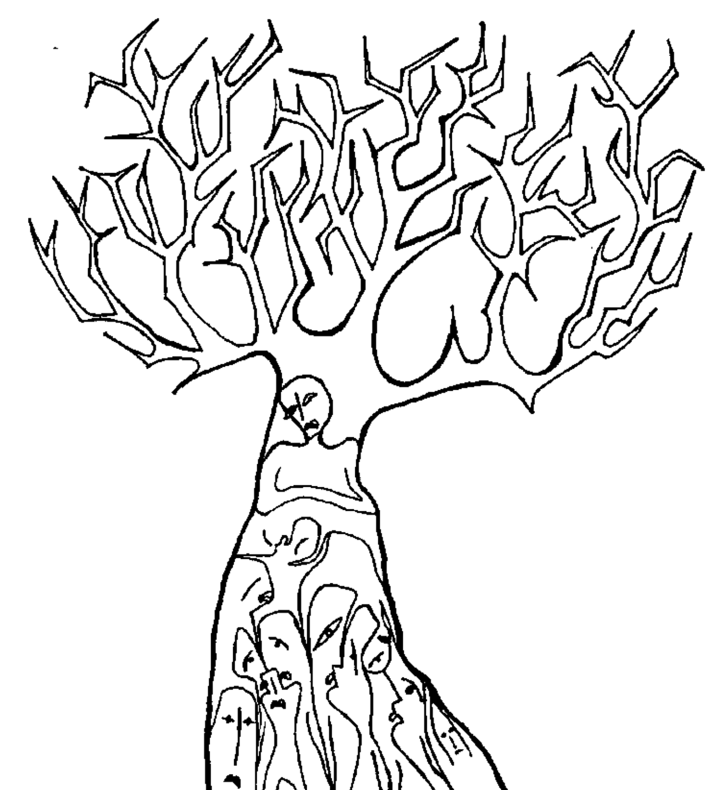
The road from the Rio Earth Summit is still unpaved. Paving the road would mean working toward resolving the environmental and social problems that plague the Amazon and its population. Unfortunately, of the many promises and plans that came out of the Summit, few have been addressed. The extractive reserve initiative, created to provide a sustainable alternative land use system in the Amazon, is such a plan.

Extractive reserves are conservation units within which local people have the right to live and harvest forest products. There are 18 extractive reserves in Brazil, most of them created after 1990. They encompass more than 6 million acres and recognize the land rights of more than 45,000 people. International conservation organizations like IUCN have recently recognized the importance of the extractive reserve concept for protection of forest diversity (IUCN 1992).

Extractive reserves are managed as a partnership between government and community-based organizations. However, these reserves are not working as well as they could. Few have organized marketing cooperatives to provide economic support to their members. To survive, forest dwellers are either leaving their holdings or increasing their area of slash-and-burn plots. The situation is even worse in communities outside protected areas.

The possibility that the extractive reserve initiative might fail is rooted in the lack of appropriate public policies. Existing policies that directly affect the reserves are rarely enforced, and the lack of proper pricing policies for extractive commodities has left many products with no market (IEA, 1993).

This problem persists because, at the broadest level, the government still envisions the Amazon as a frontier that must be filled with loggers, gold miners, and new highways. Thus we see a contradiction between official conservation talks and the actual policy for Amazonia. For example, the Brazilian government stated that measures for reducing deforestation rates and forest burnings have been successful (Machado 1992). However, Fearnside (1992) concluded that the economic recession played a larger role in reducing deforestation than any government policy change.



Another example of the gap between official and actual policy is the "Economic-Ecological Zoning" program for the Amazon. The stated goal of this program is to support sustainable development initiatives across the region (SAE/PR 1991). Instead of planning for the entire region, the program has focused most of its efforts on specific, strategic areas of the Amazon. A good example is the connection between this policy program and the efforts to develop the controversial BR-364 highway to the Pacific Ocean.

There are ways to pave the road from Rio, but non-governmental organizations will have to step into the policymaking process to force a change in government behavior. Brazil has a new democracy, and there is a great deal of room for maneuvering at the political level. Success of the extractive reserve initiative may depend on these changes.

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THE ECONOMIC POTENTIAL OF A TROPICAL RAINFOREST IN VERACRUZ, MEXICO

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INTRODUCTION

Research in economic botany has focused on inventories of useful forest products such as fruits, medicinal plants and construction timber, mainly through ethnobotanic surveys (e.g., Hill 1952, Lewington 1990). In most references the quantification of the values for these diverse products is missing. Thus, often it is not clear whether these useful products are important sources of wealth or more of a curiosity.

Peters et al. (1989) demonstrated that extraction of a number of products from an Amazonian mixed-species forest site was economically superior to cattle ranching or forest monoculture plantations. Similar results were found in a forest in Ecuadorian Amazonia by Jahnige et al. (1993). Balick and Mendelsohn (1992) showed the comparably high value of medicinal plants from two forest plots in Belize. We carried out a study to analyze the value of natural tropical forest in a Mexican site. Participating researchers were Matthew Quinlan (Yale University, Calhoun-College), Miguel C. Sinta V. (Mexico City), and Miguel A. Sinaca C. (Laguna Escondida, near the site). The results have been published in two TRI working papers (see Ricker et al. 1993a, 1993b).

STUDY SITE AND METHODS

Research was carried out in the summer of 1993 at the biological research station Los Tuxtlas in the Mexican state of Veracruz. The research station was built on a 700 hectare reserve in 1967 by the Institute of Biology of the Universidad Nacional Autónoma de México (UNAM). It is located 33 km from the cities of Catemaco and nearby San Andrés Tuxtla on one side, and 4 km from the Gulf of Mexico on the other side. The reserve ranges in altitude between 150 m and 650 m, while the surrounding volcanic Sierra de los Tuxtlas reaches 1700 m. The area has an average temperature of 27°C (monthly means range from 17°C to 29°C), and a mean annual rainfall of 4750 mm. The climate has some seasonality with a drier season from March to May, and a season of storms ("nortes") in November. The soils are of volcanic origin and appear to be heterogeneous (Gómez-Pompa 1973, Estrada et al. 1985, Dirzo et al. 1987). About 84% of the original forest was lost during the period 1967 to 1986 (Dirzo and García 1992). Most of the forest has been converted to cattle pasture.

For this study four rectangular plots were chosen within the reserve, each with the dimensions of 100 m x 25 m, together resulting in an area of one hectare. The plots were chosen under the criteria that they represented "typical" forest in regard to tree size and stand density. Each tree with a diameter of 10 cm or more at breast height was tagged and numbered. Miguel Sinaca, a local resident, was able to identify the common names of all plant species from the ground. Through the use of the taxonomic inventory from Ibarra (1985) and Ibarra and Sinaca (1987), it was possible to translate the common names of all tree individuals into scientific names.

Local uses for the species on the site were described by Miguel Sinaca, as well as obtained from the literature (Chudnoff 1980, Chavelasand Gonzalez 1985, Ibarra 1985, Echenique-Manrique and Plumptre 1990). Prices of fruits were obtained on the markets in San Andrés Tuxtla and Catemaco. From the species with marketable fruits, in July 1993 only *Pouteria sapota* (Jacq.) H. Moore & Stearn (Sapotaceae, "mamey") and *Dialium gianense* (Aublet) Sandw. (Leguminosae, "paquis") were represented on the market in San Andrés Tuxtla. For fruits of three other species- - *Astrocaryum mexicanum* Liebm. ex Mart (Palmae, "chocho"), *Diospyros digyna* Jacq. (Ebenaceae, "zapote prieto"), and *Pseudolmedia oxyphyllaria* J.D. Smith (Moraceae, "tomatillo")-- not in season at the time, price estimates were obtained from interviews. Fruits from another seven species, not in season, were left out of this analysis.

Miguel Sinaca provided estimates on fruit production, harvesting time, and retailing time for the trees in the plot from his experience as a long-time resident. In addition, the estimates for *Pouteria sapota* were compared with actual measurements in homegardens from Alvarez and Lazos (1983).

Transportation costs were obtained from the local transportation system in Catemaco. Timber prices were obtained from a carpentry shop in Catemaco. Data for the cost-benefit analysis for agriculture and cattle ranching were obtained from interviews with two local informants engaged in these activities. Miguel Sinaca provided economic information from his cattle ranch, agricultural fields and forest located near the reserve.

RESULTS

On the one hectare of rainforest we found 76 tree species (>10 cm dbh). Of those, 11 produced edible fruits and 27 other species were of interest for their timber. In addition, one abundant, small palm tree (<10 cm dbh), *Astrocaryum mexicanum*, was of commercial interest for its edible flowers.

The cost-benefit analysis in Table 1 shows that the sale of fruits from five naturally occurring tree species on the market in San Andrés Tuxtlas, would have resulted in a Net Return of 1473 Pesos per year for the one hectare area.

Table 1. Market value of fruit extractions from the natural forest at Los Tuxtlas

SPECIES	FRUIT PRICE[1] /unit	PRODUCTIVITY[2] /tree /year	RETURN /tree /year
1) *Astrocaryum mexicanum*	≈1.0 P/flower	1-4 flowers	1-4 P
2) *Dialium guianense*	20.0 P/kg	≈ 5 kg	≈100 P
3) *Diospyros digyna*	≈2.0 P/kg	≈150 kg	≈300 P
4) *Pouteria sapota*	2.0 P/kg	≈250 kg	≈500 P
5) *Pseudolmedia oxyphyllaria*	2-15 P/kg	≈10 kg	20-150 P

	TIME[3] /tree /year	COSTS[4] /tree /year	NET RETURN[5] /tree/year	TREES /hectare	NET RETURN /hectare/year
1)	--	≈0.8 P	>0.2 P	≈ 1000	200 P
2)	2 days	42 P	58 P	3	174 P
3)	3 d	105 P	195 P	1	195 P
4)	3 d	135 P	365 P	1	365 P
5)	1 d	23 P	7 P[6]	77	539 P
				TOTAL =	1473 P

[1]US$ 1 = 3.06 Pesos; prices for fruits of *Dialium guianense* and *Pouteria sapota* were observed in July 1993, when they were in season; prices for the other fruits are based on estimates from local people;
[2]Some fruits (seeds) are excluded for controlled regeneration of the tree(s);
[3]TIME is the estimated time for one person in days for harvesting (including going to and returning from the tree) and selling on the market (including going to and coming from the market);
[4]COSTS include a labor cost of 20 P /day, a cost of 10 P /100 kg for transportation with a horse from the forest to the street, and 20 P /100 kg with a truck service from the street to the market in San Andrés Tuxtla (transportation costs include one accompanying person);
[5]Net Return = Return - Costs
[6]A price of 3 P/kg is assumed - with 2 P/kg there is no Net Return.

Pouteria sapota was the most valuable of the five fruit species analyzed; a single large tree would have been responsible for 25% of the Net Return from the one-hectare forest area (see fruits in Figure 1).

Most species in the plot were of interest for their timber. However, a cost-benefit analysis of selling timber from this site in the market in Catemaco showed that at current prices and current transportation costs, the timber had no value in the market at Catemaco (a loss of 155 P/cbm; see Ricker et al. 1993a). Standing timber has a Net Return only at sites closer to the timber market, where transportation costs were lower.

Figure 1. Pouteria sapota *fruits for sale in the market in Catemaco*

In an economic comparison with land use for cattle ranching and agriculture, it turned out that selling the fruits of the five naturally occurring tree species on the market in San Andrés Tuxtla resulted in a Net Return three to four times higher than cattle ranching at the same site (362 P/ha/year), while market agriculture was not profitable (a loss of 780 P/ha/year) (Ricker et al. 1993a). The single large tree of *Pouteria sapota* had about the same Net Return as the nearby one-hectare cattle pasture.

DISCUSSION

At the investigated forest site in Los Tuxtlas, extraction of natural products would outcompete agriculture or cattle ranching. The value of the forest lies largely in its edible fruits. This result shows the high value that natural tropical lowland rainforest can have.

Of particular importance for this result is the productivity of *Pouteria sapota*. Fruits of *P. sapota* from the market weighed on the average 0.5 kg per fruit. For the large *P. sapota* tree in our plot, we estimated an average productivity of 500 fruits per year, resulting in 250 kg per year. Alvarez and Lazos (1983) reported similar measurements from homegardens with 500 fruits per tree per year, but they reported a somewhat lower total weight of 167 kg per tree per year. It is possible that their trees were smaller and produced smaller fruits.

The estimate of the Net Return of the whole hectare area is conservative in that the following seven fruit tree species bearing edible fruit were not included in the analysis: *Brosimum alicastrum* Sw. (Moraceae, "ojoche"), *Couepia polyandra* (H.B.K.) Rose (Chrysobalanaceae, "olozapote"), *Genipa americana* L. (Rubiaceae, "yuale"), *Pithecellobium* aff. *hymenaefolium* (Kunth in H.B.K.) Benth. (Leguminosae, "muchite"), *Poulsenia armata* (Miq.) Standley (Moraceae, "abasbabi"), *Pouteria campechiana* (Kunth in H.B.K.) Baehni (Sapotaceae, "zapote niño"), and *Rheedia edulis* (Seemann) Triana & Planchón (Guttiferae, "limoncillo"). Some of these fruits are also sold on the market when in season (in particular *Pouteria campechiana, Poulsenia armata* and *Rheedia edulis)*, but we could not determine the prices.

Timber production on the investigated site would not be competitive at this time, given the high transportation costs and the low timber prices. Improvements in the road system, however, could lower transportation costs enough to make timber extraction profitable. Timber extraction for local construction is already profitable now. However, lower transportation costs may also increase the demand for (currently) remotely grown fruits.

The analysis raises important management issues and questions. The proportions of tree species in the forest could be altered by replacing some less valuable tree individuals with species of greater value. Such management would have costs in terms of time commitment (labor) and possibly the need to apply pesticides. Very little is currently understood concerning alternative management strategies, both biologically and economically. Will a monoculture of *Pouteria sapota* trees or an "enriched" mixed-species forest be economically optimal? (This issue is discussed in Ricker et al., 1993b).

The high economic value of the standing forest suggests that conservation of the remaining natural forest in the region would be economically sound. Further research should focus on the management and marketing of natural fruit trees from the forest.

ACKNOWLEDGMENTS

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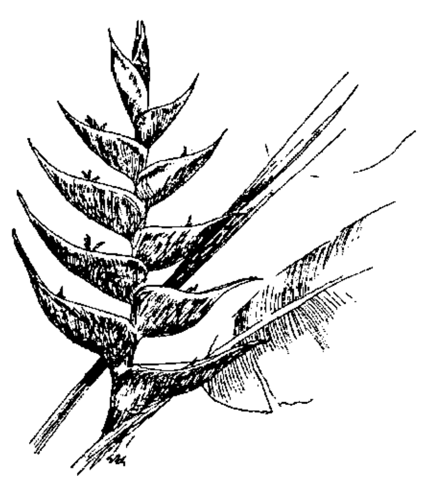

THE ECONOMICS OF SUSTAINABILITY: DISTRIBUTION OF PRODUCTION COSTS OF THE BRAZIL NUT (*Bertholletia excelsa* HUMB. & BONPL.) IN PERU AND BOLIVIA

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INTRODUCTION

Because of the low international Brazil nut price in 1992, processing plants offered a low price for the raw material. Brazil nut gatherers, or *castañeros*, could barely cover the cost of harvesting with the price offered, and most elected not to harvest nuts during that year (Munn, *personal communication*; Ricalde 1993). Instead, they turned to other activities, such as timber harvesting, cattle raising (Ricalde 1993), and selling their labor. The first two activities involve forest depletion and deforestation. Cattle raising, as it is practiced today, involves degradation of residual Brazil nut trees.

The health of the Brazil nut industry is thus important for forest conservation in Peru and Bolivia, as it allows local people to make a living in the rainforest without depleting the forest and its resources. Since profits in the Brazil nut industry are set by international markets, the easy way to increase revenues is by reducing production costs. In order to identify ways of doing so, I conducted a study during the summer of 1993 of Brazil nut processing costs, from nut gathering to dry kernel exporting, in Bolivia and Peru. In this paper I will discuss this study and its results and attempt to highlight the points in Brazil nut processing that have the largest cost share and their relevance for exporters and gatherers profitability.

METHODS

I conducted formal interviews with Brazil nut gatherers (close to twenty-five from both countries), managers and owners of export companies, officers from government agencies, and consultants from non-governmental organizations (NGOs). Brazil nut gatherers were patient respondents and did their best to remember their expenses, costs, prices, number of nuts sold, and their timing. Exporting companies were sometimes suspicious about the information requested but there were only a few cases in which they did not help me. The information obtained is by no means complete and the results must be analyzed with caution. Circumstances during my visit to both countries made me weigh the time spent in each country differently. I obtained more information from gatherers in Peru and from exporting companies in Bolivia. This bias is reflected in the paper.

Brazil nut gatherers' costs were calculated from data obtained during the interviews. Since household members do not receive wages for their work, the cost of their participation was calculated as the opportunity cost of hiring independent workers. The wage rates used in these calculations were prices paid in the surrounding area where the *castañero* worked. The cost of total household participation was calculated as the opportunity cost of those members of the household engaged in the nut gathering and transporting activities. Data for local Brazil nut prices were obtained from the owner of a concession in Planchón who had an accounting book with his transactions since 1981. Although data from Planchón could only be representative for this local area, trends in prices could be extrapolated to what happened in Puerto Maldonado as the main market. Gatherers usually do not file their transactions, and this gatherer from Planchón was a fortunate exception.

RESULTS AND DISCUSSION

Nominal prices for raw material (shelled nuts) in Planchón, on the Puerto Maldonado - Iñapari road, tend to increase during the buying period (May to December or January). However, real prices tend to go down during these periods. The pattern of diminishing real prices for shelled nuts in Planchón is shown in Figure 1 (opposite page). This shows that the activity has become less attractive for gatherers, especially during the last three years. Figure 2 (opposite page) shows the variation of both international Brazil nut real prices and weighted average real prices paid to a gatherer in Planchón. It also shows the real prices paid to the gatherer converted in US $ using the exchange rate at the time of the transaction. Prices in Planchón, expressed as US $, follow approximately the same trend as international prices. However, it is interesting to note how the difference between the international price and the price paid to the gatherer (in real US $) increases since approximately 1987. After 1988, prices paid to the gatherers in real Soles have much more of a declining trend than prices paid to exporters. The price paid in real Soles in 1992 was five times less than the price paid in 1981. Gatherers perceive this difference by comparing how many sacks of nuts, or *barricas*, they needed before and how many they need now to buy, say, a sack of rice or a motorcycle.

Figure 3 (opposite page) shows the estimated cost per *barrica* plotted against household participation. Zero percent of household participation means that the owner of the concession hired independent workers outside the household to gather and transport nuts. Those *castañeros* who did not use household labor for gathering (0% participation) were prima-

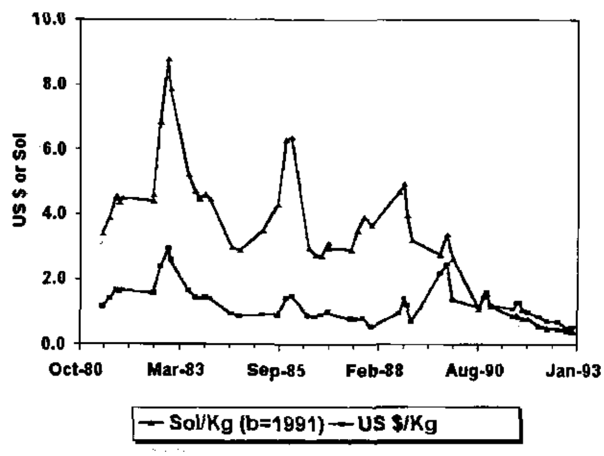

Figure 1. Prices for shelled nuts paid to a gatherer at Planchón, Peru.

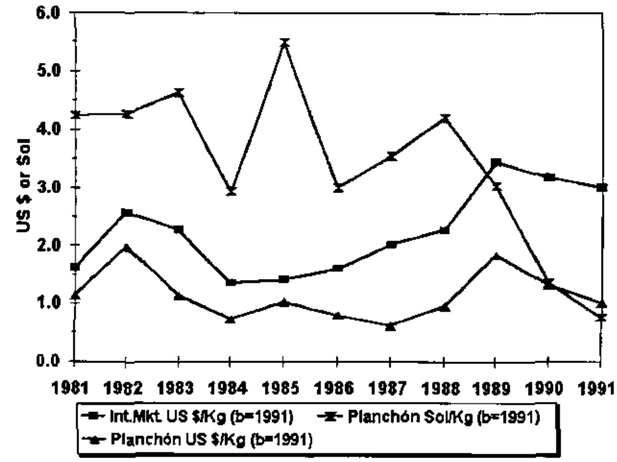

Figure 2. International and local real prices for Brazil nuts.

rily owners of small businesses, such as stores, bars, and restaurants. Some of them have small children or single daughters that cannot do the hard work ofgathering. Mainly, they have access to cash to pay the workers. Typically, high household participation is associated with lower income families. The data, which must be considered preliminary, suggests that as household participation increases, so does the production cost. This would be true because of the high opportunity cost of working in Brazil nut gathering within the household. As the *castañero* faces low income and available labor in the household, he will use more of this available labor, which is perceived as cheap.

The other aspect shown in Figure 3 is the high production cost for some gatherers compared with the price paid by the Bolivian exporters in 1993. Again, the high opportunity cost of the work done by household members is not accounted for by the market price for the raw material. The next best alternative for gatherers would be to work for somebody else rather than working in their own concessions. Apparently, this alternative does not provide a strong incentive for the gatherers. The high opportunity cost could be explained by inefficiency due to inexperience of young household members and time spent socializing during the activity. Since the socialization is desirable, it would decrease the opportunity cost, lessening the disincentive.

Raw material in the form of in-shell nuts is the more expensive component of Brazil nut production for exporters (see Figure 4). Raw material can account for 26 - 50% of total costs. The lower raw material percentages come from cooperatives, one in Bolivia and the other in Brazil. Cooperatives pay a higher price for raw material to their associates than the market price. The low percentage of raw material in total costs for cooperatives can be explained by higher wages paid to shellers, selectors, and other workers, as well as inefficiency in processing, especially in shelling.

The price paid for the raw material is directly correlated to the international price (see Figure 2 and Figure 5, next page). To reduce costs, exporting companies in Peru monopsonized prices before 1992. However, the presence of Bolivian buyers in Maldonado in 1993 blocked any attempt to do so. Demand for raw material made exporting companies go to the gatherers rather than waiting for them in Puerto Maldonado. Although buyers discount raw material prices due to trans-

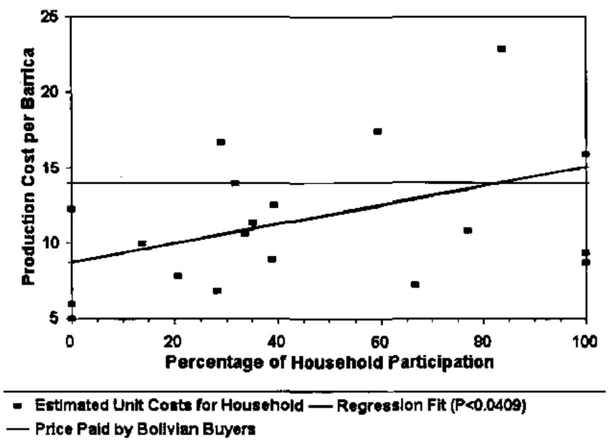

Figure 3. Production cost versus household participation.

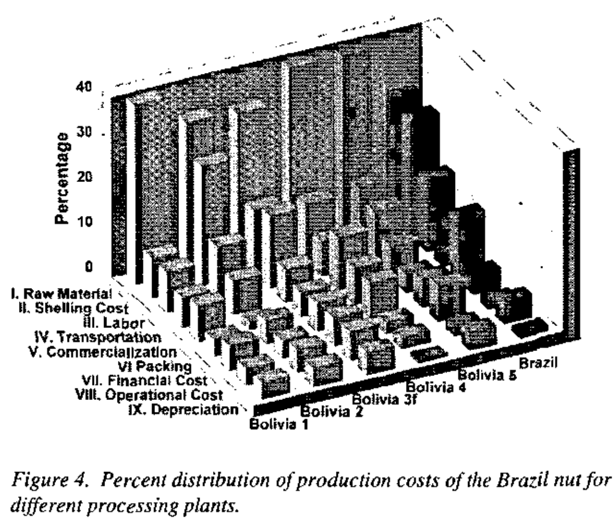

Figure 4. Percent distribution of production costs of the Brazil nut for different processing plants.

portation costs, some gatherers appeared to receive a good price. This is especially true for those *castañeros* who have no means of transportation and have to pay a third party. Personal relationships, such as kinship, friendship, and *compadrazgo,* allow some gatherers access to cheaper or even free transportation. When international prices rise, exporting companies have an incentive to sell nuts and they will try to expand their sales. Because other companies will have the same incentives, buyers will raise raw material prices to buy more quantity (at a higher price, suppliers will sell more quantity). Even if the buyers try to monopsonize the market, to avoid paying higher prices, they will need to raise the price to increase the overall supply of raw material.

Transportation also has an important share in Brazil nut total costs and figures in almost every part of the process. Transportation costs vary by gatherer and can be as large as 60% of a *castañero*'s total cost. Costs of transporting raw material from the forest to the gatherer's center or to the producer's facilities, and therefore the profitability of a Brazil nut stand, depend on: i) proximity of the Brazil nut tree stands, ii) accessibility (by boat, dugout-canoe, truck, tractor, motorcycle, bull-buggies, bulls and donkeys, or foot), iii) type of transportation available, iv) amount of nuts to transport and v) season. These factors also apply to the costs of transportation from the gatherer's center to the processing plant. Maintenance of roads, season, amount of nuts to transport, and competitiveness of cargo airfares affect costs of transportation from the processing plant to the port of shipment.

The cost of Brazil nuts produced in Peru is also affected by the U.S. dollar exchange rate (Vizcarra, *personal communication*). The exchange rate does not represent the purchasing power of Peruvian currency compared to the dollar. Figures 1 and 2 show the difference in trend between real prices in Soles and real prices in US dollars paid to one gatherer in Planchón for his shelled nuts. In 1985 and especially since 1988, these figures show the effect of the differences between inflation and devaluation of the Peruvian currency. The reasons for this discrepancy may include money speculation and the flood of U.S. dollars from narcotics traffic in the Peruvian monetary market. There is a free market of dollar exchange in Peru and there is no restriction or rule that fixes rates by the government.

CONCLUSIONS

This work suggests that as international prices increase, so does the price paid for the raw material, and thus, its cost. However, the empirical data obtained shows that in the last three to four years prices paid for the raw material have diverged from international prices. This divergence increases the profit gap between exporters and gatherers. Gatherers are not likely to continue in this activity if the profits they earn are too low. The trends in gatherer behavior

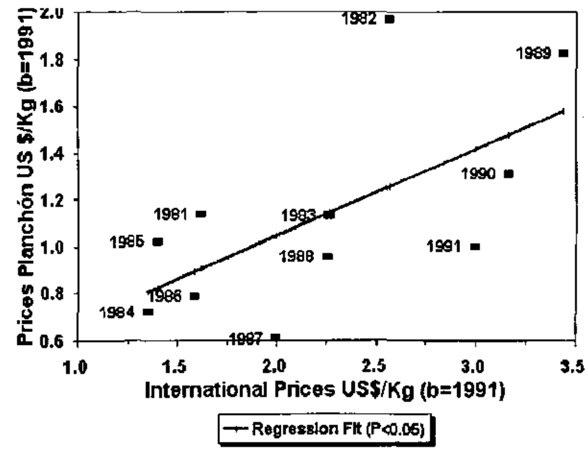

Figure 5. International price versus price paid to the gatherer.

indicate that the opportunity cost of gathering the nuts is larger than timber harvesting and cattle raising. The data obtained among the Peruvian gatherers interviewed suggest that those who employ more household labor face higher production costs, and that it would be more profitable to hire gatherers than to work ones own concession. If this is true, poor *castañeros* who realize this situation would tend to work either for those concessionaires that have access to cash, or in other activities.

The highest cost in Brazil nut processing is for raw material. The cost of the raw material changes with shifts in international prices, but it is hard to determine how these fluctuations in international prices influence the cost share of raw material in nut total costs. One hypothesis would be that the share of raw material cost will increase as the international price does. The rationale is that if only international price varies, the price of the raw material would vary in the same direction. All the other unit costs are likely to remain equal. Therefore, the share of the raw material cost and the total cost would increase if the international price increases.

Reduction of production costs is linked to infrastructure and logistics, especially for transportation costs. The monetary economy affects the profits obtained by gatherers and exporters, especially in Peru. These two factors require intervention from outside the industry and are unlikely to be affected by the actors involved in Brazil nut gathering and exporting. Instruments for cost control among exporters are increased efficiency, quality control, and decentralization of processing closer to the forest. Decentralization would help reduce transportation costs. Gatherers may increase efficiency and cooperative effort to reduce their costs.

Exporters' willingness to reduce profits for a better price for the gatherers would help support their activity and secure raw material supply. *Castañeros* need to increase their responsibility and build confidence between themselves and the companies that pay in advance for raw material. This would generate access to cash and better prices for them, and lower costs for producers and exporters.

ACKNOWLEDGMENTS

This study was possible thanks to the invaluable support of the Tinker Foundation and the Tropical Resource Institute. I want to thank Jason Shogren for his help and guidance. Nancy Peluso, Carol Mitchell, Enrique Ortiz, and Michael Balick gave me comments on the original proposal. Charles Munn III gave me the idea for the work. I am indebted to the Brazil nut gatherers from Madre de Dios, Cobija and Riberalta. I want to thank the exporter companies and all their people that received me, especially Gastón Vizcarra. Thanks to all other people that gave me their time and that I do not mention here. Thank you Mayu for all your support and your love.

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THE ECOLOGY OF BAYLEAF PALM (*Sabal morrisiana*) AND IMPLICATIONS FOR ITS SUSTAINABLE MANAGEMENT IN THE RIO BRAVO CONSERVATION AND MANAGEMENT AREA, BELIZE.

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INTRODUCTION

During the late 1980s, public awareness of tropical forest destruction inspired a range of new conservation strategies. Among these new strategies, perhaps one of the most prominent was the proposal that the extraction of nontimber forest products could prevent rainforest destruction (Anderson 1990, Soemarwoto 1990).

This strategy was based on two factors: first, that forest dwellers have extracted nontimber forest products for thousands of years without destructively altering the environment, and second, that in order to ensure successful land conservation, land resources must remain accessible to local populations. This type of extraction was further supported by the creation of a green market which enabled consumers to use their purchasing power to support the creation of environmentally sound products.

The question remains, however, will the harvesting of nontimber forest products promote forest conservation? Although marketers of rain forest products would lead us to believe that this strategy is already definitively saving tropical forests while supporting local economies, many questions remain unanswered. There is little information available on levels of sustainable harvest, ecological requirements for growth, and ecological functions of many nontimber forest product species (Soemarwoto 1990).

If properly managed, harvesting of nontimber forest products may offer an effective alternative to more destructive uses of forest resources (Prance 1990). On the other hand, over-harvesting of key species can potentially endanger not only the extracted species but other interconnected species as well (Soemarwoto 1990).

In order to study questions and issues pertaining to the sustainable harvest of nontimber forest products, I developed a research project on *Sabal morrisiana*, or bayleaf palm, as it is locally known in Belize. The goal of this project is to design a monitoring system which will enable the sustainable harvest of *S. morrisiana*. My first objective was to gather ecological information to aid in understanding this species. With funding from the Tropical Resources Institute, I created a study to determine soils favorable for growth of bayleaf palm. Reported here are the preliminary results. I plan to continue this research as a doctoral student in order to develop a monitoring system to determine sustainable levels of bayleaf palm leaf harvest. This monitoring system will be used by Programme for Belize, a Belizean nonprofit land conservation organization, in an effort to sustainably manage and conserve this resource. It is anticipated that this monitoring system can serve as a model for the extraction of other nontimber forest products. In addition, the ecological and monitoring information will be useful for local harvesters of this resource.

Species Description

Although *Sabal* spp. are found throughout the new world tropics, it appears that *Sabal morrisiana* only occurs in the Petén region, which comprises parts of Guatemala, Mexico and Belize. Due to its limited range, the widespread destruction of its habitat, and its utility as a nontimber forest product, *S. morrisiana* is a potentially endangered plant species worthy of scientific study.

Resource Use

Sabal morrisiana is of significance for several reasons. Its leaves are harvested for both subsistence and market use in the construction of thatched roofs for work shelters, homes and resort cabanas (Fig.1, below). Leaves are typically cut by local people in the construction of roofs for their own homes. Individuals are frequently hired as thatched roof contractors for the construction of lodge or resort roofs.

Figure 1. Belizean workers constructing a thatched roof.

Due to its resistance to marine borers and salt water, bayleaf timber is used in the construction of docks and piers (Soler, *personal communication*). In addition, the heart of this palm is eaten for both nutritional and medicinal purposes (Soler, *personal communication*; Rhodas, *personal communication.*). The harvest of bayleaf timber and palm heart kills the plant, while the harvest of leaves does not. Because the former two uses are more destructive and it appears there is not a high demand for these products, I have focused my attention on the potential of harvesting *S. morrisiana* leaves.

Resource Management

In Belize, *S.morrisiana* is currently managed in the following ways. Leaves are harvested from natural forest stands. Essentially this means that resource users go to an area where they would expect to find an abundant, naturally-occurring population of bayleaf. Typically dense bayleaf stands occur in low-lying areas, near rivers or seasonal streams. Here, soils are deep and tend to have seasonal standing water. Palm abundance facilitates collection and transport of the leaf product.

The harvesting area may be on government or private land. When land is privately owned, the harvester may either offer products or services in exchange for the leaves or pay an agreed price per leaf. When land is owned by the government, the harvester typically pays a set price per leaf (Soler, *personal communication*).

Leaf harvesting typically occurs between the full moon up until two days before the new moon (Soler 1993). Reportedly, leaves harvested outside this period deteriorate significantly more rapidly than those cut in the correct phase of the moon (Harding 1992, Soler 1993). Ideally, all but two leaves are harvested from each individual plant. Two young leaves are left intact in order to ensure future growth (Rhodas 1993, Rivas 1993, Soler 1993). Unfortunately, this practice is not always followed. It is common to find whole trees felled for the harvest of leaves, a technique which kills the plant. In this situation the timber is wasted and left at the harvesting site. Whole tree harvesting can potentially jeopardize the future viability of this species as it is believed that a tree must be 15-20 years old before it will fruit (Soler 1993).

Not all of the harvested leaves are used. A good thatch leaf must be neither too young nor too old, must be a certain size, and must be pliable to enable easy workability (Rhodas 1993, Rivas 1993, Soler 1993). Many of the leaves do not fit the above requirements. However, they are harvested because this action promotes access to good leaves.

In addition to leaf-harvest, bayleaf palms are commonly left standing during the preparation of *milpas* (swidden and fallow agriculture) and pasture land (Horwich and Lyon 1990). Most likely, these individuals are left in order to provide shade and thatch leaves. To date, I have not found evidence that bayleaf is cultivated in Belize.

SITE DESCRIPTION

The Rio Bravo Conservation and Management Area is an 82,000 hectare reserve which is located in northwestern Belize between 17° and 18° North. Programme for Belize holds this property in trust for the people of Belize and manages it for the purposes of conservation and sustainable economic development (Brown 1991).

According to the Holdridge system, this region is classified as subtropical moist semi-deciduous forest (Hartshorn 1984). Mean annual rainfall is approximately 1500 mm. January to May are considered dry months while the rest of the year is comparatively wet (Brokaw and Mallory 1993). The soils in this area are derived from limestone, and the topography is comprised of level and gently sloping areas, hills, and escarpments (Brokaw and Mallory 1993).

Approximately 1000 years ago, this area was occupied by the ancient Maya civilization. Since that time the forests have regrown. From approximately 1850 to 1970, the area was owned and exploited for mahogany and chicle by the Belize Estate and Produce Company. During this time, most of the harvestable mahogany trees were felled and nearly every *Manilkara zapote* was tapped for chicle, a latex which is used in the production of chewing gum. The health and productivity of *M. zapote* within this area has yet to be determined.

Within the last twenty years there has been some very limited swidden and fallow agriculture. Hurricanes have also played a role in shaping this forested area. However, despite these resource extractions and land uses, Rio Bravo's vegetation remains largely intact.

METHODS

In order to determine soils favorable for growth of *S. morrisiana*, I surveyed one hectare transects in three forest types: upland mesic, upland dry, and transitional forest. The upland mesic forest can be characterized as a mid-slope ecosystem with limestone substrates. The forest plot in the upland dry forest was placed along a topographic gradient which ranged from bottom lands to hilltops. This plot is of particular interest because it contains a distinct variety of soil textures and moisture contents. The transitional forest occurs at the base of hills and is characterized by seasonal standing water and deep clay soils.

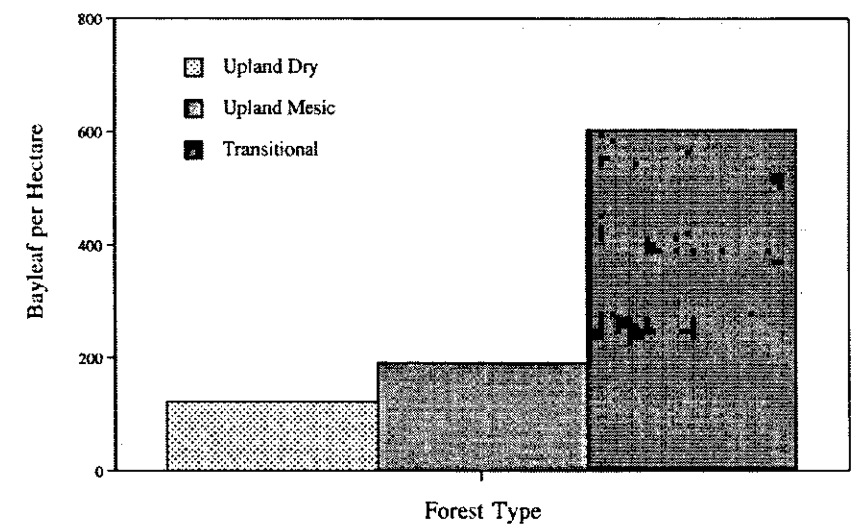
Each transect was divided into fifty 10m x 20m cells. Within each cell all *S. morrisiana* were identified, mapped, measured for height, crown diameter and leaf size, and the total number of leaves and new leaves per plant were counted. Landscape features and the presence of indicator plant species were also noted. Typically these indicators species are representative of a particular habitat or vegetation type. In addition, soil samples were taken within each cell in order to determine soil bulk density, pH, total soil nutrients, and soil moisture.

PRELIMINARY RESULTS

Preliminary analysis reveals that the transitional forest contained the highest number of individual bayleaf trees per hectare, followed by upland mesic and then upland dry forest (Fig.2).

Data from the upland dry forest, which was surveyed on a topographic gradient, shows that bayleaf population densities were greatest in low slope areas and smallest on hilltops (Fig.3). This may indicate that *S. morrisiana* favors wetter conditions and finer soil textures.

Generally, height class distributions decreased as height increased. Among the eight height classes, height class 1 showed the greatest spatial variation between forest types. Spatial variation ranged from 32 individuals in upland dry forest to 303 individuals per hectare in transitional forest. The variance decreased for larger height classes. The greatest differences in height classes within forest types occurred between classes one and two.



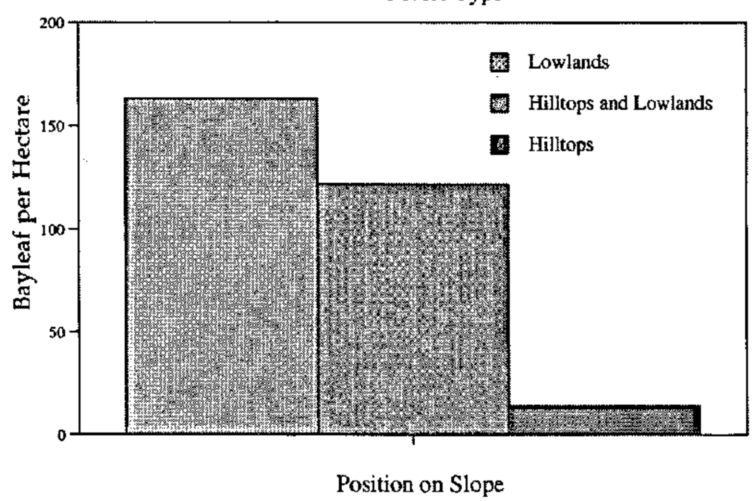


Figure 2 (top) shows the number of bayleaf trees per hectare for three forest types. Figure 3 (bottom) shows bayleaf densities along topographic gradient in upland dry forest.

CONCLUSION

Preliminary results indicate that *S. morrisiana* tends to favor moist, deep clay soils at the base of slopes. This information can be used to assist Programme for Belize with the management and harvest site selection of this nontimber forest product species within the Rio Bravo Conservation and Management Area.

In addition, this information, combined with the results from the leaf tissue and soil nutrient analysis, will be used in the creation of a harvesting monitoring system which I plan to create as part of my doctoral studies. It is anticipated that this monitoring system will serve as a model for the sustainable harvest of other nontimber forest product species.

I have chosen to study *S. morrisiana* in order to aid in the collection of information which will lead to the sustainable harvest of nontimber forest products. The viability of nontimber forest product harvesting as a means of conservation and nondestructive use of tropical forests must be further studied before assumptions can be made regarding the efficacy of this conservation strategy. Information must be generated regarding levels of sustainable harvest, ecological requirements for growth, and ecological functions of nontimber forest product species. Questions of sustainability must be answered before tropical forests are seriously damaged and also before conscientious consumers become disillusioned with this marketing tactic.

ACKNOWLEDGMENTS

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DEVELOPING A CONSERVATION PROJECT TO SAVE THE ATLANTIC RAINFOREST OF SOUTHERN BAHIA

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The Mata Atlântica, or Atlantic Rainforest, is a lush, highly diverse tropical rainforest which once covered an area of over one million square kilometers in Brazil. Stretching from the northeastern state of Rio Grande do Sul, the forest extended along the coast nearly to the Uruguayan border (Mori 1983, Conservation International 1993). The history of this forest is deeply intertwined with the history of Brazil. Over the past five hundred years, this forest has been logged for brazilwood (*Caesalpina echinata*) and valuable hardwoods such as *jacarandá*, the brazilian rosewood (*Dalbergia nigra*); cleared to make way for pastures and sugar cane and coffee plantations; and burned to produce charcoal for the steel mills of Minas Gerais (Dean 1983). Today, less than 5% of this forest remains, scattered over hundreds of tiny, disconnected fragments (Conservation International 1993).

Yet despite the nearly complete destruction of the Atlantic Rainforest, it is still a more biologically diverse forest than the Amazon Rainforests. In 1993, for example, a team of researchers from CEPLAC (The Cacao Research Institute) and the New York Botanical Gardens announced that they were able to catalogue 450 different tree species in just one hectare of Atlantic Rainforest in southern Bahia, making it the most diverse forest in terms of tree species in the world (Brooke 1993). Furthermore, the remnant forest fragments provide important environmental services, such as watershed protection, to many of Brazil's largest cities, and are still a source of lumber and charcoal in some regions, especially southern Bahia.

Though the rate of deforestation has greatly decreased over the past ten years in most of the former territory of the Atlantic Rainforest, it is still rampant where the forest is most diverse and most threatened: in the southern portion of the state of Bahia where less than 7% of the original forest cover remains. In this project, I examined the historical and present causes of deforestation in southern Bahia (see Fig. 1) with the objective of formulating a conservation project for a specific portion of the region.

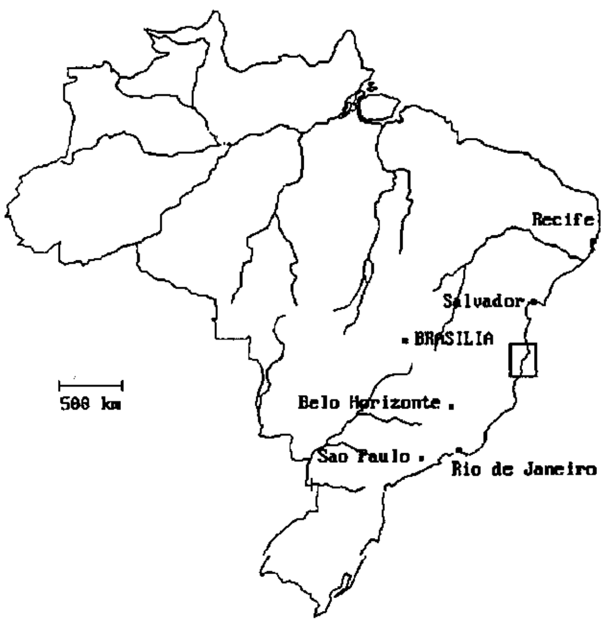

Figure 1. Map of Brazil. Boxed area represents southern Bahia region studied by author.

During a two-month visit to the region I interviewed farmers, loggers, sawmill owners, cattle ranchers, researchers, environmentalists, foresters and government officials, including mayors of several municipalities and foresters and guards of IBAMA (the federal environmental protection agency). This survey was not a systematic study of the region to obtain quantitative data on present rates of deforestation. Instead, the survey was a personal reconnaissance, acquainting me with the region, its people and its problems, so that a plan of action for conserving and recovering the region's forests could be developed.

I found that despite historical exploitation of forest resources since the establishment of the first Portuguese settlements in the sixteenth century, large-scale deforestation in southern Bahia is a relatively recent occurrence. In fact, large-scale deforestation began in the early 1970's, coinciding with the opening of BR 101, a federal highway that cuts through the region, linking Rio de Janeiro with Salvador.

With the opening of BR 101, sawmills in the north of the state of Espírito Santo, which had greatly depleted the local resource base, gained access to vast stretches of nearly virgin forest. Spurred by government incentives and extremely cheap land prices, dozens of sawmills established themselves in the region between Eunápolis and Itamaraju, making logging the most important economic activity of the region. However, forests were quickly harvested with no attention to sustainability and forest regeneration. The ensuing high deforestation rate is a classic example of the consequences of the short-term, rapid return mentality all too common among Brazilian capitalists and businessmen. Forest lands were essentially free and seemingly boundless, and thus there were no incentives for conservation and sustainable practices. Despite its recent and expected decline due to the depletion of the forests, logging is still the second most important economic activity in the Eunápolis region, and sawmills are found in every municipality of southern Bahia. Though law now requires sustainable management plans to be submitted to and approved by IBAMA before any site can be logged, many sawmills completely disregard this law, and night-time illegal operations are quite common.

The opening of BR 101 also allowed cattle ranchers to take advantage of cheap land prices and move into southern Bahia. Their practices of pasture formation and management are incompatible with local soil and environmental conditions, leading to rapid land degradation. Pasture is created by first logging an area; remaining forest is then felled and burned to make charcoal (see Fig.2, next page). The rancher himself earns very little money from the logs and charcoal. His advantage is that loggers and charcoal producers clear the land for free. Despite its poor quality, the exposed soil is then directly seeded with *Brachiaria humidicola* or *B. decumens*--two species of pasture grass--with no prior enrichment or treatment.

Pastures are typically managed with one or two annual burns, which ranchers believe renovate them. In reality these burns only accelerate the decline in productivity by sterilizing the soil and volatilizing nitrogen. These burns also destroy regeneration of native vegetation. On average, active pastures in southern Bahia support less than one head of cattle per hectare, and are productive for only 5 to 10 years.

In general, I found that in southern Bahia, forest is seen as a free good that exists only to be exploited or felled. There is little awareness of the environmental services provided by forests or of the consequences of deforestation on quality of life. Many of those interviewed expressed the opinion that there is still much forest left, and that "forests never end."

Given the small amount of remaining forest cover, and the high rates of deforestation (SOS Mata Atlântica, a São Paulo-based NGO, used satellite data to estimate that as much as 90,000 hectares are deforested yearly in southern Bahia), it is clear that immediate action must be taken if any portion of the Atlantic Rainforest in southern Bahia is to be saved. For this purpose, I have founded, together with two collaborators, an NGO which will develop and implement a pilot conservation/sustainable development project in the District of Cumuruxatiba, in the Municipality of Prado.

This region still has 30-40% of its forest cover intact but is threatened by logging and clearing by small farmers and cattle ranchers. The project will take a multidisciplinary approach toward conservation, consisting of a series of modules. Each sub-project will address a specific issue such as environmental education, rural extension, agroforestry, mapping/environmental monitoring, and forestry. As the first step in the formulation of the project, from May to August 1994, I will conduct a base-line detailed socio-economic survey in Cumuruxatiba in order to identify the ranchers, loggers, and small farmers operating in the region. Project proposals for each module will then be written and funding will be sought from private and government foundations in the US and Brazil.

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Figure 2. Charcoal producers in Cumuruxatiba, southern Bahia.

PATTERNS OF BANJ OAK (*Quercus leucotrichophora* A.Camus) REGENERATION IN THE CENTRAL HIMALAYAS

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INTRODUCTION

The inadequate regeneration of *banj* oak (*Quercus leucotrichophora* A.Camus) in the Himalaya has been reported by foresters in India for over 50 years (Troup 1921, Saxena and Singh 1984, Singh and Singh 1986, 1992). *Banj* is the dominant oak species in the central Himalaya within a 900-1800 m altitudinal range (Champion and Seth 1968). The mild climatic conditions of this elevation zone are favorable for settlement and the region is densely populated (Dadhwal et al. 1989). Since *banj* is the main fuel and fodder tree in this region, the reported regeneration problems of this species is a cause of widespread concern.

Difficulty in the regeneration of oaks has also been reported in the United States (Downs and McQuilkin 1944, Merritt 1979), and Europe (Pigott 1983). Proposed causes of regeneration failure include: the lack of viable seeds due to insect or animal predation (Marquis et al. 1976), a lack of acorn germination and seedling establishment, and grazing of seedlings by domesticated animals (Pigott 1983) or deer (Marquis et al. 1976). In the Himalaya, low regeneration has been attributed to all the causes mentioned above. *Banj* acorns are commonly infested with weevils that can significantly lower germination rates (Dwivedi and Mathur 1978, Kaushal and Kalia 1989). High population densities of humans and cattle subject the forests to intense grazing pressure (Mohan and Puri 1955). This has been cited as one of the chief causes of low *banj* regeneration (Singh and Singh 1992).

The objective of this study is to determine if *banj* regeneration in the central Himalaya is sufficient to maintain the dominance of this species. I hypothesize that adequate *banj* regeneration may occur in all but the most disturbed habitats.

METHODS

Study Sites

Twenty-nine oak-dominated stands were studied in three different sites in the central Himalaya in the state of Uttar Pradesh, India: the Pranmati watershed (30°10' N, 79°32' E) located in Chamoli district; Binsar (29°43' N, 79°46' E) in Almora district; and the Indian Veterinary Research Institute (IVRI) forests near Mukteshwar (29°29' N, 79°39' E) in Nainital district. Altitudes vary between 1800 and 2200 m. This area has a seasonal climate with warm summers (17 - 26°C) and cool winters (4 - 10°C). The annual precipitation is approximately 1200 mm, most of which occurs as rainfall during the three monsoon months (July-September). About 20% of the precipitation occurs in the winter and at higher forest elevations a substantial part of it is in the form of snow. The period preceding the monsoon (March-June) is dry and the vegetation is subject to water stress. This can result in high oak seedling mortality.

Sampling Design

I selected stands based on the presence of *banj* and classified them by their legal property status into sanctuary or state preserves (31% of plots studied), reserve or state forests (25%), *van-panchayat* or village-owned (23%) and private forests (22%). Seedlings were considered woody regeneration <1 meter in height and saplings as regeneration ≥1 m tall but less than 10 cm diameter at breast height (DBH).

I established transects through all stands, and laid down a set of nested plots at 50 m intervals along each (usually 3-4 plots per transect). Within 25m^2 circular plots, I counted all *banj* seedlings and saplings. In a 100m^2 circular plot encompassing the first, I measured all trees ≥10 cm and identified them by species to determine the overstory stand structure. The canopy cover above regeneration was determined using a densiometer.

RESULTS

The stands studied had a high basal area, averaging 35 m^2/ha. The mean canopy cover was about 60%. These figures normally would not indicate forests that require any new regeneration.

Differences in regeneration and canopy structure were found among forests under different tenures (Table 1, next page). These forests differed in the degree of human activity, with sanctuary forests being the most protected and village forests being the most disturbed. Reserve forests were often heavily grazed and lopped, especially those that occurred close to villages. The number of *banj* trees was significantly greater in village forests (457/ha) and private forests (475/ha) than reserve forests (91/ha), with sanctuary forests having an intermediate number of *banj* trees (255/ha).

Seedling numbers were lowest in the sanctuary forests (520 seedlings/ha), highest in private and reserve forests (2080 seedlings/ha), and intermediate in village forests (1240 seedlings/ha) (Fig.1). High numbers of adult *banj* trees did not correlate with high numbers of seedlings. In fact, fewer

Table 1. Table depicting the regeneration (seedlings and saplings), tree structure (number, basal area, canopy cover) in forests under different ownerships. Letters qualitatively indicate significant differences (a>b>c) according to Fischer's PLSD post hoc test (α=0.05).

	Private	Reserve	Sanctuary	Village
No. of plots	20	23	29	21
Trees/ha	600 (a)	478 (a)	655 (a)	610 (a)
Banj/ha	475 (a)	91 (c)	255 (b)	457 (a)
Basal Area (m^2/ha)	39 (a)	39 (a)	35 (a)	31 (a)
Canopy	61 % (a)	66 % (a)	63 % (a)	53 % (a)
Seedlings/ha	2080 (a)	2080 (a)	520 (b)	1240 (ab)
Saplings/ha	40 (b)	348 (a)	192 (ab)	172 (ab)

seedlings and saplings were found in plots which had a high number of adult trees. Though the variability of seedling number was high, a regression of adult trees versus seedlings, showing an inverse relationship, was significant at $p < 0.05$.

DISCUSSION

The variation in numbers of adult *banj* trees between stands is probably more a reflection of the basis for reserve classification than any type of management practice. Forests with a larger component of commercially important pine were, in the past, frequently classified as reserve forests. *Banj*-dominated forests are of limited commercial value to the state, but important to the local villagers, and were thus classified as village forests.

Human induced disturbance, mainly from grazing by domestic animals, has been cited as the cause of low oak regeneration in the central Himalayan forests (Singh and Singh 1992). In sanctuary forests, human disturbance is limited, and thus high regeneration would be expected. However the mean seedling number was found to be lowest in these forests, less than half the seedling number in village forests and about a fourth that of reserve or private forests. The stands studied in sanctuary forests had a high tree density and a closed canopy which allowed very low light penetration into the understory. The closed canopy has resulted from legal constraints on harvesting which have minimized timber removal. The results of a study by Rao and Singh (1989) indicate low shade tolerance in *banj* seedlings. Thus low light conditions present in sanctuary forests may result in high seedling mortality.

Levels of regeneration seem to be correlated with disturbance regimes in the other three forest types. Of the three remaining tenure types, village forests had the least regeneration. These forests are under high grazing pressure and often show a lack of regeneration of almost all species palatable to cattle, including *banj*. In addition, excessive lopping of oak trees may induce stress and cause low seed production (Singh and Singh 1992). Private and reserve forests have intermediate levels of disturbance and greater oak regeneration. Some disturbance would result in the presence of a more open canopy, thus seedlings in these forests may have better growing conditions and be more likely to survive. However, a higher grazing pressure in these forests may counteract this advantage, though not to the extent of the village forests.

My study suggests that the apparently low seedling number need not indicate the decline and replacement of *banj* oak forests in the central Himalaya. Oliver (1978) concluded that relatively few seedlings are required to regenerate a red oak (*Quercus rubra* L.) stand in New England due to low mortality of established seedlings. Hence the presence of few seedlings relative to other tree species is not necessarily indicative of regeneration failure.

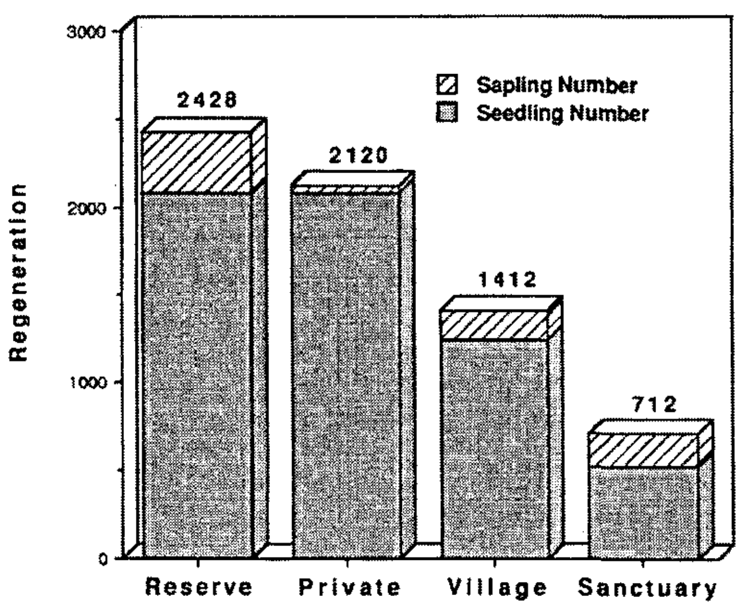

Figure 1. Regeneration in forests under different tenurial regimes

In protected areas, regeneration is low, associated with overstories with high basal area, stem density and canopy coverage. Saxena and Singh's (1984) finding of no seedlings of any species in a *banj* forest would suggest that these stands are in the stem exclusion phase (after Oliver & Larson 1990) of stand development, where the absence of light due to a dense canopy excludes all new regeneration.

This study would thus indicate that *banj* regeneration is not as much a problem as has been previously thought. Given sufficient openings in the canopy and some protection from overgrazing, sufficient regeneration is likely to occur to prevent the replacement of *banj* from the central Himalayan forests.

ACKNOWLEDGMENTS

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POST-DISPERSAL SEED PREDATION BY TERRESTRIAL VERTEBRATES IN GUNUNG PALUNG NATIONAL PARK, WEST KALIMANTAN, INDONESIA

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INTRODUCTION

Most tropical tree species are locally rare, existing at densities of about 1 adult per hectare (Primack and Hall 1992). This scarcity poses a challenge for the conservation and management of tropical forests especially in light of increasing rates of deforestation and habitat fragmentation. Understanding the recruitment patterns of tropical trees is necessary for making predictions about how they persist and about how species diversity is maintained.

Predation has been shown to limit the germination and establishment of tree species throughout the tropics (Janzen 1970, Connell 1971, Wilson and Janzen 1972, Howe and Smallwood 1982, Augspurger 1983, Leighton and Leighton 1983, Clark and Clark 1984, Coates-Estrada and Estrada 1988). Coates-Estrada and Estrada (1988) found that post-dispersal seed predation by mammals strongly reduced recruitment at the seed and seedling stage of one species they studied in Mexico, although effects on later stages were not discussed. In contrast, Hubbell (1980) concluded that seed predation would not limit tree species abundance on Barro Colorado Island, Panama.

Ongoing research in West Kalimantan, Indonesia suggests that predation may be important in lowland dipterocarp forests for at least two reasons. First, seed rain is typically very low outside of infrequent masting events, causing seed densities on the forest floor to be as low as one seed/5m^2/ month (Leighton, *unpublished data*). In addition, terrestrial predators in these forests, primarily rodents, pigs, and porcupines, are adept at finding isolated dispersed seeds (Knab and Leighton, *unpublished manuscript*).

These data suggest that predators could dramatically influence successional patterns and subsequent forest composition in lowland mixed dipterocarp forests (Leighton 1990a, Knab and Leighton, *unpublished manuscript*). For some species, more than 75% of dispersed seeds could be destroyed (Howe and Smallwood 1982). If predators prefer seeds of more common species, post-dispersal seed predation could provide a mechanism for rarer species to persist.

The goal of this study was to further elucidate the role of post-dispersal seed predators in limiting regeneration of rainforest trees. Specifically, I tried to ascertain what types of dispersed seeds are most subject to vertebrate seed predation and what percentage of viable seeds escape from vertebrate seed predation. I also conducted laboratory experiments with caged spiny rats to test for preferences of seeds based on size and texture (results to be published in forthcoming TRI Working Paper).

METHODS

Study Site

The 15 km^2 Cabang Panti Research Station (CP) is situated at 1°13'S, 100°7'E in the 100,000 ha Gunung Palung National Park (GP), West Kalimantan, Indonesia. The elevation in CP ranges from sea level to 1000m. Annual rainfall at CP is about 4500mm, but distinct dry periods occur during February and July-August. Seven habitats can be found within the study area including peat swamp, freshwater swamp, alluvial bench, lowland sandstone, lowland granite, submontane and montane.

Field Trials

I conducted 4 field trials in which I measured the predation rates for approximately 40 tree species in lowland sandstone habitat. In each trial, I established 4 replicates, placing identical groups of seeds along 4 ridge trails which served as transects. Only a few species of seeds were repeated in successive trials due to temporal variation in fruiting. In each trial, I used 9-15 species; replicates comprised 3-11 seeds depending on the species' availability. The collected seeds had diverse physical characteristics. After cleaning each seed (removing arils or pulp), I weighed and measured the testa (seed coat) thickness of a subsample of each species.

In all 4 trials, I placed individual seeds at randomly assigned locations at least 5m from the trail and at least 3m from each other. Only one seed was placed at each location to assess the predators' ability to find isolated seeds. I placed all seeds on one trail in the field on the same day. For the first two weeks I monitored them every other day for signs of predation. Subsequently, I checked on the remaining seeds every 4 - 7 days for at least 1 month. I recorded whether or not the seed was present or missing. If the seed was present I noted if it had toothmarks, was partly or totally eaten.

Analysis

I calculated predation values by dividing the cumulative number of seeds missing, eaten or half-eaten after a particular day by the total number of seeds I placed for a trial. For this article, I used analysis of variance to test for significant

Table 1. Mean seed weight, testa thickness, and predation rates for Days 21 and 30 by seed size.

Size	N	Mean Weight (g)	Mean Testa Thickness (mm)	Mean Predation Day 21	Mean Predation Day 30
Small	502	0.29±0.007	0.153±0.004	0.65±0.3	0.69±0.31
Medium	535	1.42±0.027	0.456±0.021	0.44±0.23	0.48±0.23
Large	505	6.49±0.127	1.39±0.22	0.33±0.22	0.38±0.24

differences in predation rates for different size classes. However, these size classes are somewhat arbitrary because seeds do not come in discrete size intervals; the continuous nature of these data lends itself to regression analysis. In the working paper, I will present results of multiple regression analysis, specifically testing for differences in predation over time that can be explained by seed weight, testa thickness, or an interaction of the two variables.

RESULTS

Predation rates ranged from 0.00 (*Canarium denticulatum*) to 1.00 (*Sterculia stipulata & Roureopsis acutipetala*) for days 21 and 30 over the 4 trials. Seed weight ranged from 0.1g (*Baccaurea stipulata & R. acutipetala*) to 11.6g (*Ternstroemia magnificum*). Testa thickness ranged from 0.1mm (several species) to 4.65mm (*C. denticulatum*). Table 1 summarizes the mean seed weights, testa thicknesses and predation values after day 21 and day 30 for the 3 different size classes (this table will be presented in greater detail in the working paper). A one-way ANOVA followed by a Tukey test indicated a significant difference in predation rates between large and small seeds ($F=6.59$, $df=2/44$, $p<0.01$; see Fig.1). Predation tended to decrease with both increasing seed weight and seed coat thickness. Seed weight and seed coat thickness were positively correlated (Pearson coefficient = 0.683).

DISCUSSION

The large range of predation rates across seed taxa implies that seed species have different vulnerabilities to post-dispersal predation. In the field, seed predators had little difficulty finding and consuming isolated, dispersed seeds. Significant results in the field trials suggest that seed size and texture are important determining factors for predation pressure on different seed taxa. Larger seeds (>2g), especially those with very hard, thick (>1.0mm) seed coats tended to suffer less predation than smaller seeds or seeds with thinner seed coats.

The implications of these results are interesting from both an evolutionary and an ecological perspective. For example, it is possible that coevolutionary forces have strongly shaped the composition of this forest community. The changing preferences of predators over time for nutritionally-rich seeds, combined with the ability of these predators to penetrate the seed coat or digest toxins may have provided strong selection pressures for the evolution of greater chemical and physical defenses. The same argument can be extended to the predators; seed defenses exerted selection pressures for the evolution of greater ability to detoxify seed poisons or penetrate thick seed coats.

Species that are sparsely distributed in the forest may be able to persist if relatively common species suffer more predation than relatively rare species and if predators have greater preferences for the more common ones. An alternative hypothesis is that the maintenance of species diversity occurs

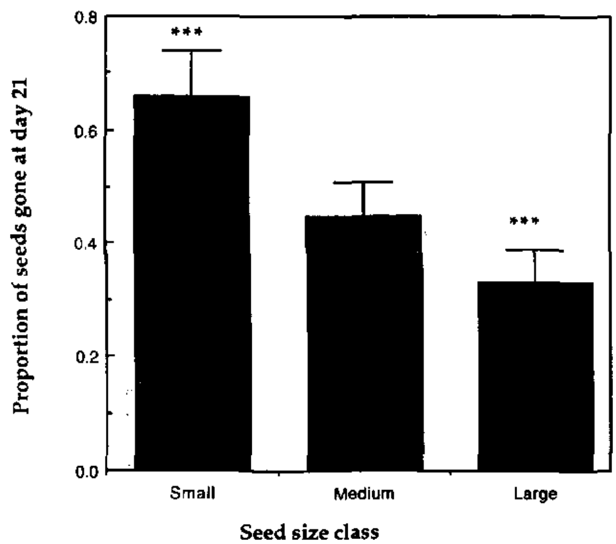

Figure 1. Predation rates for 3 size classes of seeds.

through stochastic processes. The preference of seed predators for seeds is complex and depends on a suite of phenomena including seed morphology, nutritional benefit, chemical defense, abundance, and availability relative to other taxa. Future studies should try to integrate morphological, chemical and nutritional characteristics of seeds with annual fruiting patterns and the relative predation rate of these taxa.

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DISTRIBUTION PATTERNS OF THE INVASIVE MEXICAN THISTLE, *Argemone ochroleuca*, IN A NAMIB DESERT RIPARIAN ECOSYSTEM

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INTRODUCTION

Argemone ochroleuca Sweet (Papaveraceae), an annual from Central America with spiky, deeply-lobed leaves, prickly seed capsules and many tiny, toxic, water-dispersed seeds (Ramakrishnan and Jeet 1972, Jabs 1991), has been listed among the most invasive alien plants in Namibia, including the Namib-Naukluft Park (Vinjevold et al. 1985, Boyer and Boyer 1989). Several authors report *A. ochroleuca* (Fig.1, opposite page) distribution across the Kuiseb River: this species tends to occur in open sandy riverbeds and flood-plains (Tarr and Loutit 1985); it inhabits the central riverbed region of desert ephemeral rivers along with other annual or relatively short-lived perennial alien plant species (Boyer and Boyer 1989); and it occurs on the northern side of the riverbank (Jabs 1991). These reports lack accompanying definition of riparian regions as well as quantification of the plant's distribution.

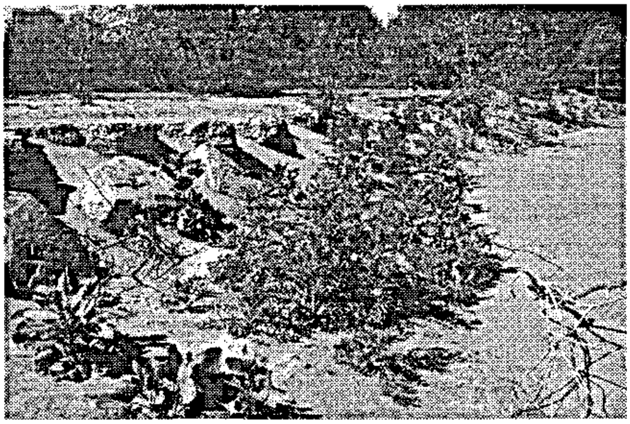

Figure 1. Dense clump of Argemone ochroleuca *(center of photo) growing in the Kuiseb River.*

Ecological Setting

The approximately 440 km-long Kuiseb River is one of several seasonal rivers in Namibia and one of the largest, most important rivers in the Central Namib Desert (Seely et al. 1981). In the Namib Desert, the Kuiseb flows roughly westward, forming the border between the northern gravel plains and the southern Namib Dune Sea (Van den Enyden et al. 1992). Floods at Gobabeb, 65 km upstream from the current reaches of the Kuiseb, occur between December and April, and open water holes may persist through May. The flow results in a recharge of underground reservoirs, a clearing of ephemeral vegetation and sand that encroaches from the southern dune sea, and an influx of seeds from upstream (Seely et al. 1981). Six floods reached Gobabeb, home of the Desert Ecological Research Unit (DERU) between 29 January and 10 April 1993.

Differential disturbance from inundation and scouring--due to floods and an interaction of basin geology, hydrology and inputs of organic and inorganic matter--result in channel zonation and subsequent variation in distribution and species composition of vegetation in riparian systems (Gregory et al. 1991). Gregory et al. (1991) refer to the geomorphic landforms associated with river valleys as active channels, floodplains, terraces and alluvial fans. They add that the boundaries, or banks, of the active channels are often abrupt, signifying the lower extreme of perennial vegetation and that floodplains may extend great distances. Introduced species, which tend to form dense, monospecific stands, often drastically transform rivers and other aquatic habitats (MacDonald and Frame 1988).

This study examines the likelihood of *A. ochroleuca* to inhabit one or a combination of the following zones of channel morphology: floodplain north (FPN), transition zone north (TZN), main river channel (RIV), transition zone south (TZS), and floodplain south (FPS). In order to decide whether or not this species should be targeted for active control and removal, it is necessary to determine the degree of infestation and the range of distribution.

METHODS

The study site encompasses 8 km of the Kuiseb River near Gobabeb, Namibia (Fig.2). Coordinates of the most upstream transect were 23°33.93' S and 15°03.12' E. I selected transect sites upriver and downriver from the Desert Ecological Research Unit (DERU) at Gobabeb, and from the Sout River village 5.1 km (linear channel distance) downstream from Gobabeb. No transects were placed in vehicular entrances or other localized points of disturbance. I chose six transect sites, both where the river channel was straight and where it bent (at the apex), and paced approximately midway between the first set of transects to site the remaining four.

Transects were 1m wide and ran approximately north to south, perpendicular to the flow of the river. For each transect, I placed markers on both sides of the perpendicular axis and sighted back to the northern, gravel plain side terminus, which I determined by farthest presence of flooding evidence, including vegetation debris, sorted material or considerable topographic rise coupled with typical gravel plain substrate. The presence of reddish iron oxide-coated dune sand signified the southern dune sea terminus. The main river channel (RIV) was generally the lowest, fairly flat, central portion of the river. Transition zones (TZN and TZS) grade up relatively quickly from either side of the main channel whereas the floodplains (FPN and FPS) rise more

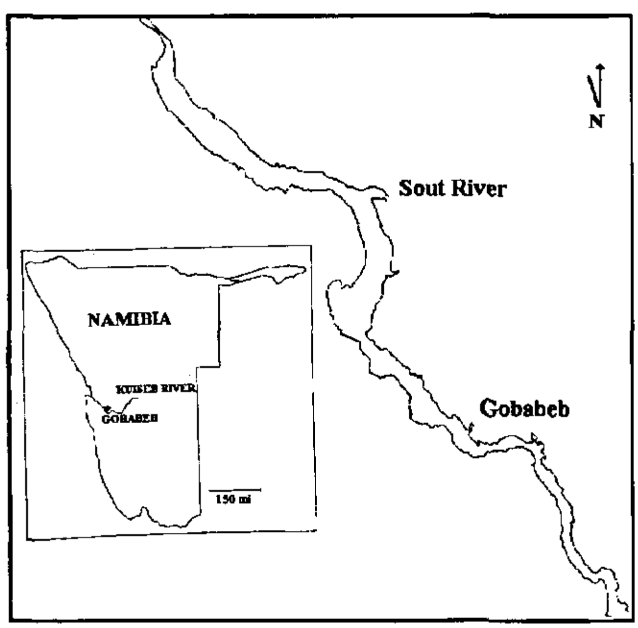

Figure 2. Kuiseb River study area, Namibia.

gradually outward from the transition zones. I determined the coordinates of each transect with a global positioning system (Garmin GPS 50, Taiwan) as well as the linear distance from the water pipe at DERU from a vehicular odometer.

For each plant that occurred along the transects, I recorded the river zone, distance from the northern transect terminus to the nearest 0.1 m, species, and size. Size consisted of height and maximum width for herbaceous plants and shrubs, and diameter at breast heigh (dbh) for all trees.

I divided each transect according to the five channel zones designated in this study. I then extracted all information concerning *A. ochroleuca*, including the occurrence of each individual, and its planar area (height times maximum width). I compared the density and planar area of *A. ochroleuca* by five zones in ten transects and ran an analysis of variance (ANOVA) to determine statistical significance.

RESULTS AND DISCUSSION

Table 1 shows the mean density and planar area by zone and the p-values from single factor ANOVA tests, $p = 0.412$ for density and $p = 0.460$ for planar area. No statistical significance exists to indicate a zonal pattern in *A. ochroleuca* distribution, either in number per area or planar unit per area.

Table 1. Summary of A. ochroleuca *distribution.Mean density (number of plants per m^2) and mean planar area (height x maximum width per m^2 in the five zones (+/- standard deviation). See text for abbreviations. Bottom row shows the results of a single factor ANOVA, n=50.*

Zone	Density (plants/m^2)	PLANE AREA (cm^2/m^2)
FPN	0.180 ± 0.557	68.151 ± 21.392
TZN	0.489 ± 1.318	141.179 ± 384.964
RIV	0.036 ± 0.064	7.184 ± 20.270
TZN	0.003 ± 0.011	0.341 ± 1.080
FPS	0.025 ± 0.040	10.993 ± 24.034
p-value (s.f. ANOVA)	0.412	0.46

Boyer and Boyer (1989) suggest that the direct impact of this alien species on native vegetation may be slight because few indigenous plants are known to dwell in the riverbed, and recommend no eradication for this alien species. A lack of statistically significant differential distribution of *A. ochroleuca* among the five zones appears contrary to the observations of Boyer and Boyer (1989) as well as to that of Jabs (1991), who writes that the plant occurs on the northern side of the riverbank. This study suggests *A. ochroleuca* presence extends to all five zones, rather than just the main river channel and transition zone as previous papers imply.

Interestingly, Boyer and Boyer (1989) attribute a higher density of this plant in the upper stretches of the Kuiseb River to a greater frequency of flood waters upstream than downstream. The Kuiseb River catchment area on the escarpment upstream from the Namib-Naukluft Park serves as a seed bank for many of the river's alien plant species. Moody and Mack (1988) hold that removal of large populations of a plant invader is not effective in eliminating the species, due to the high degree of stochasticity operating in small populations. Therefore, reintroduction of *A. ochroleuca* by seasonal floods from upstream is likely unless management includes *radical* control of *upstream* sources.

MacDonald and Frame (1988) call for early control of invasions which imperil nature reserves. Usher (1988) suggests that more recent invaders have a greater impact on host communities than longer-established invasive species. DERU herbarium samples document presence of *A. ochroleuca* in the study area as early as 1972. What are the population dynamics of this invader, and how do they affect the Kuiseb community over time?

Decisions to remove this species in the Kuiseb River should be made after determining the temporal stage and degree of this invasion as well as the extent and trends of its impact on the community. Should *A. ochroleuca* have a substantial and/ or increasingly negative impact on the Kuiseb community, control measures should be explored. Such management should be intensive and focus on the catchment area upstream as well as downstream locations.

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REHABILITATING FERNLANDS IN THE DIPTEROCARP RAIN FORESTS OF SRI LANKA BY RE-INITIATING SECONDARY SUCCESSION

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INTRODUCTION

Throughout the dipterocarp rain forests of Sri Lanka's Wet Zone, complete forest clearance and prescribed burning for crop cultivation, followed by abandonment, has favored establishment of one species of exotic fern, *Dicranopteris linearis* (Gleicheniaceae). This species is a pioneer exploiting disturbed lands in wet tropical climates (Maheswaran and Gunatilleke 1988). After *D. linearis* becomes established, its dense cover can arrest forest regeneration almost indefinitely (Joachim and Kandiah 1942) because microsite conditions are not suitable for buried, windblown, or animal dispersed tree seeds to establish and develop into second growth forests (Hafeel 1991).

Attempts at converting fernlands back to forest have included the establishment of *Pinus caribea* (Caribbean pine) or *Fragraea fragrans* (Tembusu) plantations (Weeraratna 1949). These exotic species do not emulate the complex structure and function of a dipterocarp rain forest. By comparison, ecological rehabilitation may repair certain successional processes (Aronson et al. 1993) and therefore favor the recovery of forest structure and function. The objective of this study was to verify if a site treatment could rehabilitate fernlands by initiating a successional process that would facilitate eventual colonization of primary and secondary forest tree species. Until now, no study has used such an approach to restore secondary vegetation on sites occupied by *D. linearis* in the Asian tropics.

Research throughout the tropics has suggested that soil seed banks are an important component of early tropical forest succession (Symington 1933, Enright 1985, Young et al. 1987, Rico-Gray and Garcia-Franco 1992, Chandrashekara and Ramakrishnan 1993). Young et al. (1987) found that post-disturbance recruitment of seedlings from soil seed banks numerically overwhelmed that from seed rain and sprouts. Furthermore, in wet and moist tropical systems, the density of buried seeds increases with soil depth (Skogland 1992), although this increase may be a function of vegetation age.

In an effort to rehabilitate fernlands and understand the importance of soil seed banks in a Sri Lankan rain forest, I hypothesized that revegetation dynamics, including seedling species diversity, biomass accumulation, total percent cover, and seedling density, would increase with increased soil disturbance.

METHODS

I conducted my experiment in the northwest buffer zone of Sinharaja Man and Biosphere Reserve (11,000 ha), located in southwestern Sri Lanka between 6° 21'- 6° 26' N and 80° 21'- 80° 34' E. Even before its designation as a Man and Biosphere Reserve (MAB) in 1978, the landscape surrounding Sinharaja forest was fragmented by *D. linearis*. Rehabilitating fernlands in the buffer zone of the Sinharaja MAB and conserving its flora and fauna is important because it is Sri Lanka's largest relatively undisturbed forest containing endemic taxa of the lowland Wet Zone (Ishwaran and Erdelen 1990). The reserve has steeply dissected parallel ridges and valleys aligned east-west and ranging in elevation from 90-1170 m. The climate is aseasonal with a mean temperature of 18-27°C and a mean annual rainfall of 4,000-5,000 mm, principally from the monsoons in May-July and November-January (Gunatilleke and Gunatilleke 1980). One year before and during this experiment, drought conditions were present in February.

I selected three fernlands within 1000 m of each other with equivalent canopy height (1 m), elevation (380 - 450m), aspect (NE), and slope (between 25° to 30°). As a result of controlling for these factors, and due to the irregularity of fernland shape and area, site size varied: Site 1≅200m^2, Site 2≅100 m^2 and Site 3≅36 m^2. The age of fern vegetation depended on time since last fire: Sites 1 and 2 were burned 10 years before and Site 3 was burned 20 years before this experiment. Consequently, Site 3 contained a humus layer of dead fronds and shoots with a mean depth of 10 cm and a mean root mat of 8 cm mat, whereas sites one and two possessed a mean humus layer and root mat of 1-2 cm each.

At each site, I demarcated three 14m x 5m plots, spaced 5 m apart. The centers of each plot were 17m from the forest edge, and no plot was less than 7 m from a forest edge. In each plot, I delineated four 1.5m x 1.5m subplots 1m from each other and 1.5 m from the plot edge in a linear fashion. I randomly applied three site treatments that removed fern biomass and a control that left fern intact in the four subplots. This design provided three replicates per site of each treatment and nine total replicates. Soil disturbance treatments included clean weeding (CW), root severing/ removal (RR) and tilling (T)--listed in order of increasing depth of soil disturbance and fern rhizome destruction. CW involved removing above-ground living phytomass and humus. RR and T both included clean weeding with additional severing and extracting of rhizomes to a depth of 5 cm. T consisted of forming a series of 7 to 8 troughs/ridges from the mineral and organic soil layers to a depth of 10 cm. Roots of *D. linearis* were severed to a 20 cm depth. In Site 3, these treatments involved peeling off a 10 cm root mat before severing and extracting the remaining rhizomes or tilling the soil. Subplots were further demarcated into six quadrants and permanently coded on posted aluminum tags.

From Aug. 1992 to Aug. 1993, seedling abundance was recorded from by species code on weeks 2, 4, 12, 16, 21, 26, 34, 43 and 55. Total percent cover was estimated at week 40. During the same period, total plant biomass was collected from two sub-samples in each subplot (total of 0.75 m^2), oven dried at 85°C and weighed by species.

Seedling diversity was computed for every subplot by treatment from Brillouin's Formula (H) for absolute diversity because all the individuals from a collection were identified and counted: $H = C/N\ (\log_{10}N! - \Sigma \log_{10}n_i!)$, where C is 2.302585 (constant for conversion of logarithms from the base 10), N is the total number of individuals in the subplot and $n_1, n_2, \ldots, n_i$ are the abundance for each species. Because H measures the diversity of an entire community, it has no standard error and any two different values of H are, therefore, significantly different. I performed single and two-way analyses of variance to determine the influence and interaction of treatment, site and block on data from dry weight (g/m^2), total percent cover and seedling density (number/m^2). Seedling density was analyzed for all observation periods, but only weeks 2, 12, 26, 34 and 55 are presented in this paper.

RESULTS

I recorded a total of 38 species, 31 genera and 15 plant families during one year of monitored post-disturbance vegetation recruitment, including 13 perennial herbs, 11 grasses, 2 sedges, 7 shrubs, 4 early successional tree species and 1 woody vine. The principal shrubs recorded were *Hedyotis* spp., *Hibiscus furcatus*, *Melastoma malabathirica* and *Osbeckia octandra*. Tree species that germinated included *Macaranga peltata, Phyllanthus debilis, Schumacheria castanaefolia* and *Trema orientalis*. I recorded no species recruitment other than fern in the control plots.

Seedling species diversity indices between CW, RR and T were significantly different throughout the year (Fig.1). After six months and one year, respectively, seedling diversity in RR treatments (1.5383 and 1.4591) was greater than T (1.1982 and 1.3794) and CW (1.2372 and 1.2791). Results for biomass accumulation showed a significant difference (P=.0037) among sites, but not for treatment, replicates or their interactions. Irrespective of treatment, biomass accumulation in Sites 1 and 2 was greater than Site 3 (Fig.2) at a significance level of P=.0086 for Sites 1/3, P=.0016 for Sites 2/3 and P =.4855 for Sites 1/2. Total percent cover did not vary significantly among sites or treatments, yet total percent cover for the control was significantly greater than treatments.

Table 1 (next page) shows the changes in seedling density during one year of revegetation among treatments for all sites. Seedling density varied significantly among treatments principally in Site 1 but not in Sites 2 or 3. Mean seedling density of Site 3 for each treatment was less than that of Sites 1 and 2. At a gross level the following trends in seedling density appeared before February: for site one, CW RR>T, for site two, T>CW≥RR, and for site three, RR≥ T>CW. For all sites, combined seedling density in RR>T>CW until February, and thereafter RR≥CW>T. The factors of site and replicate had no significant influence on seedling density throughout the duration of the study.

DISCUSSION

The results of this research will provide the basis for future rehabilitation of fernlands in Sinharaja MAB and elsewhere in the Wet Zone of Sri Lanka. In the past, fernland rehabilitation at Sinharaja forest involved clearing *D. linearis* in narrow paths and planting shade-tolerant primary tree saplings of *Shorea* spp. and *Dipterocarpus* spp.. This effort did not establish vigorous trees or promote secondary forest succession because *D. linearis* reoccupied the growing space cleared for saplings.

By comparison, the treatment methods examined in this study demonstrated that a soil disturbance in fernlands or above ground removal of *D. linearis* can facilitate the initiation of forest succession. Post-treatment seedling recruitment was principally attributed to seeds germinating from a soil seed bank. Support for this claim is partially based on three field observations: seed germination occurred on the underside of all soil ridges formed from tilling, an unlikely position for animal- or wind-dispersed seed; only a few mature individuals of any species represented in the revegetation were seen at the forest edge or in the fernland; and no herbaceous species were found prior to the experiment underneath the fern canopy, but two weeks after treatment they were conspicuous. Moreover, Young et al. (1987) documented the total seed rain input during 9 weeks in a forest clearing in Costa Rica as only 11 ± 11 seeds/m^2 for seeds trapped and germinated in sterilized soil--an insignificant number relative to the seedling density of 1000 individuals/m^2 they recorded after only 12 weeks.

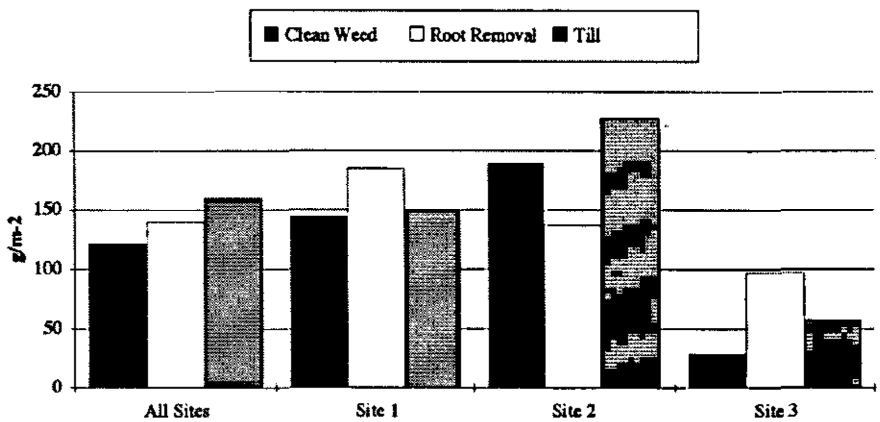

Figure 1. Mean absolute seedling species diversity between treatments (n=9).

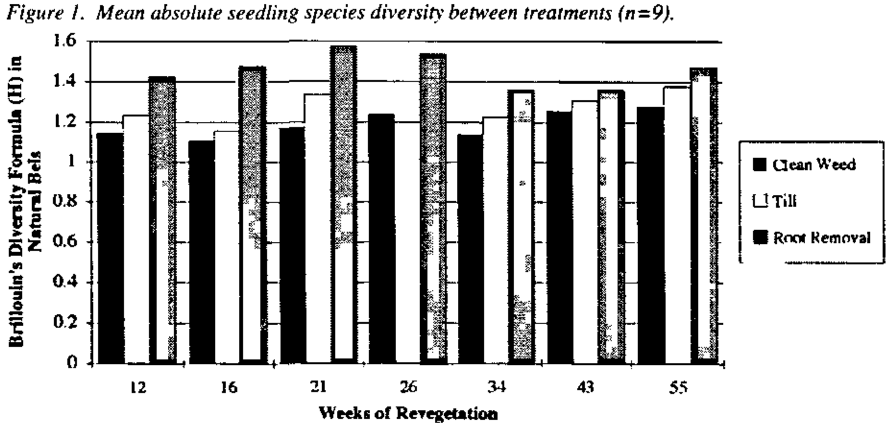

Figure 2. Mean bimass accumulation after 10 months of revegetation among sites and treatments (n=9 for all sites and n=3 for individual sites).

The influence of rhizome removal and increasing the depth of soil disturbance on

Table 1. Pairwise comparisons of seedling density among treatments over one year of revegetation for individual sites (n=3) and all sites combined (n=9).

Treatment Combinations	Week 2	Week 12	Week 26	Week 34	Week 55
			Site One		
Clean Weed/Root Removal	69/103**	254/257	322/367	219/252	359/293
Clean Weed/Till	69/33**	254/111**	322/173*	219/101**	359/137**
Root Removal/Till	103/33**	257/111**	367/173*	252/101**	293/137*
			Site Two		
Clean Weed/Root Removal	35/53	187/168	263/292	277/34*	315/338
Clean Weed/Till	35/153	187/279	263/438	277/354	315/305
Root Removal/Till	53/153	163/279	292/438	34/354*	338/308
			Site Three		
Clean Weed/Root Removal	10/52	43/206**	74/159	76/197	82/192
Clean Weed/Till	10/49	43/151*	74/147	76/158	82/226
Root Removal/Till	52/49	206/151	159/147	197/158	192/226
			All Sites Combined		
Clean Weed/Root Removal	38/70	162/210	220/273	191/161	253/274
Clean Weed/Till	38/78	162/180	220/253	191/204	253/223
Root Removal/Till	70/78	210/180	273/253	161/204	274/223

*= P<.05, **=P<.01.

revegetation suggests that an intermediate disturbance maximizes seedling species diversity. Effects of treatments on seedling density and biomass accumulation imply that although soil seed density for pioneer species may increase with the age of fern vegetation, the process of removing thick root mats in older sites may displace substantial numbers of seeds captured in the humus layer. As a result, seedling density, biomass accumulation and percent total cover was generally less in RR and T for Site 3 than in Sites 1 and 2. Nevertheless, fernlands with a dense root mat require the surface soil to be exposed before revegetation can form cover suitable for shade-tolerant primary species to establish. Simply removing the fern canopy in fernlands with a thick humus and root mat does not facilitate secondary succession.

In younger fernlands, there is conflicting evidence to support the hypothesis that the depth of soil disturbance increases seedling density. For example, in site 2, the pattern of seedling density increased relative to the depth of soil disturbance, but in site one the pattern is inverted. Seedling density with respect to treatment may have been influenced by age of individual seeds and variation in optimal germination conditions, the patchy distribution of soil seed banks (Roberts 1981), mortality during the study, and residual soil concentrations of allelopathic chemicals from decomposing fern biomass or root exudates.

Based on this study, rehabilitation methods for re-establishing secondary succession in fernlands should be refined and tailored to the age of *D. linearis* vegetation. Root extraction, coupled with the mixing of surface and subsurface soil layers by raking, instead of tilling, should be favored in fernlands with vegetation ≥20 years to expose and distribute soil seeds more evenly. In fernlands with vegetation ≤10 years, rehabilitation must include removal of humus and root mat and the collection and redistribution of soil from these layers to minimize soil seed emigration losses.

ACKNOWLEDGMENTS

This study was made possible with grants from the Tropical Resources Institute, Rockefeller Foundation and Harvard Institute for International Development. I am indebted to Dr. Mark Ashton and Dr. B.M.P. Singhakumara for their foresight, field assistance and technical guidance throughout the study. Drs. Savi and Nimal Gunatilleke and staff at University of Peradeniya's Botany Department gave in-country support. Special thanks is extended to my field assistants B. Gunasoma, and M. Meegaskumbura. I am also grateful to Dr. Graeme Berlyn for technical support and Dr. Dan Vogt for advice on data interpretation.

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REVIEWS

Selection and Management of Nitrogen-Fixing Trees. Kenneth G. MacDicken. 1994. Morrilton, Arkansas: Winrock International, and Bangkok: FAO. 272 pp.

Rising population growth rates and an expanding need for agricultural land have contributed to rapid rates of deforestation. Land conversion to agriculture or other land uses primarily occurs on lands that are marginal in their productive capacity. Many of these marginal lands lack the nutrient base to sustain long-term cultivation of agricultural crops. In some instances, the integration of nitrogen fixing trees (NFTs) into traditional farming systems may be an appropriate way for farmers to sustain crop production. In this book, Mr. Kenneth MacDicken, currently a doctoral student at the University of British Columbia, explains the advantages and disadvantages of using nitrogen fixing trees as well as the procedures for selecting appropriate species and the tools necessary for effective management.

Part One
In Chapter 1, MacDicken discusses the advantages and disadvantages of using NFTs for reforestation or for inclusion within existing farming systems. Two major concerns for NFTs are: 1) given site conditions, can NFTs provide the desired products or services under realistic management? and 2) are NFTs best suited to meet the grower's objectives? MacDicken dispels some popular myths surrounding the use of NFTs. For example, he discusses why all legumes do not fix nitrogen, why nitrogen fixation is not always beneficial, and why inoculation may not be too complicated or expensive for small farmers. The author highlights several unresolved issues, such as differences in foliar nitrogen between NFTs and non-NFTs, the importance of within-species variation in the ability to fix nitrogen, and the importance of mycorrihiza for effective *Rhizobium* stimulation and NFT growth.

Chapter 2 provides the reader with an excellent overview of the nitrogen-fixation process. The factors influencing biological nitrogen fixation are covered in appropriate detail to give a solid foundation to the unfamiliar reader as well as provide an apt review for the experienced practitioner. This chapter also contains an excellent section on the advantages and disadvantages of estimating methodologies for N_2 fixation by legumes in the field.

Chapter 3 deals with the procedures essential to the effective management of nitrogen fixation. MacDicken discusses how to confirm nodulation of an NFT, what field methods are used for identifying trees actually fixing nitrogen, and whether inoculation is necessary for fixation. Examples of NFT response to inoculation with *Rhizobium* or *Frankia* are given for several species, as are suggestions for selection and handling of inoculants. MacDicken also discusses the silvicultural management schemes necessary to enhance the nitrogen fixation process after inoculation.

The benefits of nitrogen-fixing trees is covered in Chapter 4. Emphasis is placed on the factors affecting soil improvement such as soil organic matter, organic inputs and litter quality. Several farming system designs are presented as ways to enhance soil improvement for crop production: alley cropping, enriched fallows, intercropping and rotational block plantations. This chapter includes an exciting discussion of the increased growth that non-NFTs gain from association with a companion NFT crop.

The last chapter in Part One gives an excellent overview of how to select appropriate nitrogen-fixing tree species. A brief section discusses the general taxonomic characteristics of legumes. Environmental requirements for NFTs are also presented using the Köppen climatic classes. MacDicken discusses the end uses of NFTs, planting site description, and matching the species with site requirements. However, he warns that it may be inappropriate to match species to site requirements alone because of the lack of research available for the exact environmental requirements of many NFTs.

Part Two
In this part of MacDicken's book, 40 NFTs are described in great detail. Botanical descriptions of these species include sketches, habitat requirements, method of propagation, principal enemies, potential uses, and a species distribution map. The 40 species described are generally identified by the Nitrogen Fixing Tree Association as having the greatest economic or ecological significance.

Part Three
A collection of supplemental tables and reference tools are found in the five sections of this final part. Included are inoculation protocols and methods, pregermination treatments, listings of nitrogen-fixing species and a wood yield table for priority NFTs. The lack of research information pertaining to growth and yield for many tropical tree species prevents this table from providing more than a snapshot of potential growth for NFTs.

In general, MacDicken's book is a very useful tool for field practitioners and researchers interested in using NFTs as an option for certain farming systems. The overview of nitrogen fixation, selection procedures and brief review of important NFT species make the book a useful reference.

--Donald L. Grebner
Weyerhaeuser Center/Winrock Forestry Program

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--Sarah Cummings
Royal Tropical Institute

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NOTES & LETTERS

Participatory Natural Resource Management

Participation of local people in the management of natural resources is gradually being accepted as an effective strategy to arrest and reverse the alarming rate of resource degradation and its economic and environmental consequences.

The important factors which have contributed to this awareness include the realization that state management is limited when it does not involve local communities; the rediscovery of the rationale behind traditional systems of common property resource management; advocacy by grassroots non-governmental organizations (NGOs) for local resource management; and the successful experiences of recent initiatives involving community forestry programs, community irrigation systems, user-group managed pasture development, and joint management of forests in Asia and other parts of the world.

These recent initiatives, however, have remained country-specific and in many instances have not been documented. This obstructs both the replication of these successes as well as the evolution of mechanisms for future work involving people-centered, participatory management of natural resources.

Iacuna ICIMOD has established a program which will aim to encourage participatory natural resource management in the countries of Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. This regional initiative will synthesize inter-country experiences to identify new directions, combine conceptual work with action research and field demonstration, focus on user-groups and disseminate learnings, and provide the basis for policy-program advocacy and action. The Program will also focus on issues related to decentralization and devolution of responsibilities to local institutions and the role of NGOs and resource institutions in participatory natural resource management.

For more information contact: Anupam Bhatia, Regional Coordinator; Participatory Natural Resource Management Programme; ICIMOD; GPO Box 3226; Kathmandu; Nepal.

Community-based Research

We write with regard to the article by Pinedo-Vasquez, Vogt and Vogt in TRI NEWS 12(1):3, "Sustainable resource use and development of Amazonia: A challenge for the research community." We find the authors' criticism of research to date in the Amazon to be unfounded. The participative approach they call for--to produce scientific information for direct use of Indians and rubber tappers--has been the basis of extractive reserves all along; it is nothing new. It would never have been possible to create and implement more than 3 million hectares of extractive reserves without collaborative work and a balanced exchange of information between researchers and local populations. Is there any other way to incorporate local demand into effective public policy without establishing working relationships between researchers and locals?

Research on the sustainable use and benefits of natural resources in Brazilian Amazon extractive reserves is extremely important. Extractive reserves are one of the first and most unique opportunities to evaluate the economic, social, and environmental aspects of sustainable development in Amazonia.

Perhaps foreign researchers have been unaware of the collaborative work among researchers and locals in extractive reserves because most of the pertinent literature is in Portuguese. This may have given a wrong impression that Brazilian researchers are not aware of the methodology of participative research.

The Institute for Amazon and Environmental Studies (IEA) participated in the preliminary research efforts for the establishment of the Projeto de Assentamento Extrativista Maraca I, II, and III, financed by the U.S. National Committee for Man and the Biosphere, as mentioned in the Pinedo-Vasquez et al. article. However, we would like to emphasize that we had no opportunity for institutional participation during the implementation of this project. Criteria for research participation needs to be developed not only between researchers and local communities but also among foreign researchers and researchers in the host country.

Mary Allegretti, *President of the Board*
L. Fernando Allegretti, *Research Associate*
Institute for Amazon and Environmental Studies, Brasilia, Brazil

Tropical Timber Certification Conference

On February 5-6 of this year, the Yale chapter of the International Society of Tropical Foresters (ISTF) and TRI hosted a conference entitled, "Timber Certification: Implications for Tropical Forest Management." General questions addressed were feasibility, equity, and effectiveness of timber certification.

The consensus of the conference was that certification is *technically feasible.* However, sentiments on the *economic feasibility* of certification were divided by conservation and timber interests. The three general costs to consider are those in the actual certification process, those incurred by harvesters to come up to certification specifications, and increased costs to merchants and consumers for buying good wood. An international centralized system would most likely be more costly and less efficient than a regional or case-by-case system. The question of adequate consumer demand for certified good wood was only contested by a small faction (primarily those with timber interests). Most believed that the consumer demand is both real and large.

The enduring dilemmas of certification lie primarily in questions of *equity.* Market exclusion of certifiers that do not comply is one implicit goal of certification. However, this exclusionary process may marginalize poorer indigenous people in the certification process. There are also persistent questions of access to the certification standard formation process. Fairness in the standardization process is important but there must also be acknowledgment of the hard work already completed by certification organizations.

The *effectiveness* of timber certification was called into question when participants argued that timber harvesting is not the most significant cause of tropical deforestation. The majority of tropical timber is not exported: unregulated domestic use of timber creates a loop in the certification system. These issues undermine certification's contribution to forest conservation. Other participants disagreed. The overall consensus was that certification holds promise only if it is seen as one among many solutions.

--Paul Maykish, MES Candidate, Yale F&ES

For the complete proceedings from this conference please write to: ISTF, Sage Hall, 205 Prospect Street, New Haven, CT, 06511, USA.

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