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MANAGING RATTAN DIVERSITY FOR FOREST CONSERVATION

Principal Investigator: Stephen F. Siebert
Grantee Institution: The University of Montana

Collaborator: Jill M. Belsky
Institution: The University of Montana

Collaborator: Johanis Mogea
Institution: Herbarium Bogoriense

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Grant Project Officer: LeRoy Duvall

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Executive Summary

This project investigated the ecology and socioeconomic significance of rattan, ecological effects associated with cane extraction, and the potential of sustainable harvesting and cultivation in Lore-Lindu National Park (LLNP) in Central Sulawesi, Indonesia. Rattan gathering is important to household livelihoods throughout the region, but supplies of cane are declining. *Calamus zollingeri* is the principal commercial species, produces clusters of canes and is capable of vegetative reproduction. When canes (i.e., ramets) are cut, *C. zollingeri* sprout new ramets and neither plant nor ramet production were significantly affected by cane harvesting, irrespective of harvesting intensity over four years. There is no evidence that cane harvesting significantly affects ecosystem nutrient supplies, forest structure, or that cutting small trees to float cane to market affects primary forests. On the other hand, tree felling to extract cane is widespread and current cane harvesting rates exceed growth rates; supplies of marketable cane (i.e., > 10 m) are becoming scarce. Cultivation of *C. zollingeri* using vegetative cuttings and seeds proved to be simple, inexpensive and resulted in high initial survival and growth. However, there is limited local interest in rattan cultivation; most respondents prefer to cultivate perennial cash crops.

It is imperative that rigorous, replicated, long-term protocols be adopted to monitor direct and indirect effects associated with rattan harvesting; potential ecological effects and monitoring methods are reviewed. Widespread adoption of rigorous and standardized monitoring methods may elucidate ecological and social effects associated with rattan harvesting and provide information that can be used to modify and adapt management systems within the context of dynamic, unpredictable and chaotic ecological, social, economic and political environments. Attention to social justice and equity issues could help insure that those most dependent upon rattan benefit from investments, while simultaneously reducing forest conversion to farms.

This project contributed to the research and conservation management capabilities of The Nature Conservancy (Program Indonesia), University Tadulako, Herbarium Bogoriense, and the Indonesian Directorate General of Forest Protection and Nature Conservation.

Research Objectives

The primary objectives of this project were to investigate the ecology, local use and potential for sustainable management and cultivation of economically important rattan in the Lore-Lindu National Park (LLNP) region of Central Sulawesi, Indonesia. Specific project objectives included: 1) ascertaining the abundance and site preferences of *Calamus zollingeri* and other economically-important rattan in natural forests; 2) determining survival, growth and reproduction of economically-important rattan in natural forests; 3) determining human impacts upon rattan resources and the role of rattan-based activities in local livelihood strategies; 4) evaluating the ecological and socioeconomic viability of cultivating and managing *C. zollingeri* in natural forests and in perennial-based farms; and 5) developing a model for sustained-yield *C. zollingeri* management in natural forests and protected areas that balances local economic concerns with the conservation of biological diversity.

Methods and Results

Methods:

1) ascertain the abundance and site preferences of *C. zollingeri* and other economically-important rattan in natural forests;

Research sites were established in traditional rattan collecting areas near Moa and Au in southern Lore Lindu National Park, Central Sulawesi. Research sites were selected following a preliminary assessment of rattan abundance and utilization, and discussions with regional rattan collectors and traders.

Transects and sample plots were used to estimate rattan abundance, distribution and site preferences (i.e., edaphic characteristics, slope, canopy height, light regime and forest type). Three transects, each 10 m x 1000 m length, were established upslope in a principal rattan collection area near Moa and two additional transects near Au in 1996. Each transect was divided into 10 x 10 m plots for sampling purposes. The following data were collected in the transects/sample plots:

1) the number of juvenile and mature rattan of economic importance (i.e., those with and without harvestable ramets/canes);
2) the number and length of ramets per plant;
3) the predominant light regime (PAR) as measured by a ceptometer;
4) soil moisture characteristics as measured by a portable tensiometers; and
5) soil characteristics, including pH, available phosphorus, potassium, calcium, magnesium, exchange acidity and organic matter.

Three additional transects and the same information noted above were established in Moa in 2000 to investigate changes that had occurred over time.

2) determine seed production rates, survival, growth and resprouting rates of economically important rattan in natural forests;

Rattan seed production, survival, growth (plant and cane) and resprouting rates were evaluated by permanently marking 106 *C. zollingeri* plants in Moa and 70 in Au, and monitoring genet survival and ramet resprout and growth rates annually from 1996 to 2000. Fifteen plants were retained as unharvested controls in Moa and an additional ten in Au. Canes of marketable length (i.e., > 10 m) were harvested as desired by local rattan collectors on all other plants and the

number and length of canes recorded. Unfortunately, it was not possible to retain unharvested control plants (i.e., all plants were harvested by collectors). Detailed information one each plant was collected, including: the diameter of all canes, the number of ramets, ramet lengths, the number of root stolons, soil moisture content, and associated light regime (PAR) at the base of the plant, supporting vegetation and forest structure. Genet survival, ramet growth and resprout rates, and changes in PAR and forest habitat were re-measured in 1997, 1998 and 2000.

3) determine human impacts upon rattan resources and the role of rattan-based activities in local livelihood strategies;

Rattan extraction, use and their role in local livelihood strategies were initially investigated through rapid appraisal methods (including key informant interviews, focus group interviews, community observation and direct observation). This enabled us to locate key rattan collecting villages near LLNP. and sites for more detailed study (Moa and Au). We then conducted detailed demographic and socioeconomic studies at the household and village level in Moa and Au in 1996 and 1997 to gather information on the species, amount (volume), and seasonality of rattan collecting, and its role and importance in household and village livelihood activities. The 1997 survey involved a random sample of 25% of the village households in Moa, Au and two additional nearby villages (Gimpu and Tomua). A more detailed follow-up survey was conducted of the same households in Moa in 1999 to ascertain changes in the role and importance of rattan use and to gather more detailed information re. annual and perennial cultivation practices (i.e., shifting cultivation, irrigated rice production, permanent cultivation of coffee and cacao, livestock rearing, fishing and hunting). These data were used to assess current and potential future pressures on rattan resources, to identify major income and food generating activities, to determine the role of rattan in household livelihood strategies, to identify potential rattan management practices and their economic returns, and potential interest in *C. zollingeri* management and cultivation.

4) evaluate effects associated with cultivating and managing *C. zollingeri* in natural forests and local farms;

The potential to cultivate and manage *C. zollingeri* was assessed by monitoring wild rattan plants and initiating cultivation trials involving *C. zollingeri* seedlings and vegetative cuttings. Wild rattan seeds and vegetative cuttings were collected from the forest and sown or transplanted, respectively, in simple nurseries constructed in two villages. Following germination and initial growth, seedlings were transferred to polyethylene bags and maintained in a nursery until approximately 20 months of age. They were then transplanted to forest and farm sites. The light regime and soil nutrient and drainage conditions were assessed at each transplant site. Plant survival, growth and ramet production were assessed annually for two years (data for the first eight months are presented here). The capital and labor required to plant and manage the rattan was also recorded.

Potential ecosystem-wide effects associated with *C. zollingeri* cane harvesting were evaluated, including those associated with: ecosystem nutrients stores, the use of logs to float cane to market, and impacts of cane harvesting on forest structure.

We sampled nutrient concentrations in rattan foliage and cane, and variations between wet and dry seasons by collecting paired leaf and cane samples from five mature *C. zollingeri* rattan plants in October 1997, towards the end of an extremely dry El Nino event, and five additional paired samples in March 1999, after a long and exceptionally rainy wet season. Foliage samples were gathered from terminal leaves in the upper canopy (*i.e.*, exposed to full

sunlight), while cane samples were gathered from the middle portion of mature canes from the same plants (cane lengths varied from 20 to 40 m). Leaf and cane samples were air dried and forwarded to the Cornell Nutrient Analysis Laboratory for analysis approximately one month after collection. Samples were dry-ashed and analyzed for cations and P with an ICP (program P6010) and for N via Kjehldahl analysis. Levels of N, P, K, Ca, and Mg are expressed as a percent, while Cu, Ni, Zn, Al, Fe, B, Pb, and Mn are expressed as mg/Kg. Differences between leaf and cane nutrient levels, and between wet and dry seasons were analyzed through use of a 2-way adjusted Bonferonni ANOVA. Data that were not normally distributed were log (x +1) transformed prior to analysis.

The extent of and effects associated with cutting trees to float rattan to market were assessed through a variety of methods. Annual rattan cane production in Moa and Au was determined by recording total cane harvesting from the two villages for two years. Prior to floating downstream, canes are cut, tied into bundles and lashed to an air-dried floater log (i.e., to float the fresh canes which are heavier than water). To determine average bundle weight (rattan is sold by weight based on diameter size classes), we weighed 20 cane bundles selected at random in both Moa and Au. We measured the length and diameter of 20 randomly selected floater logs in both villages and interviewed rattan collectors regarding the tree species used and the locations where harvested. Finally, we collected specimens of each tree species for subsequent identification. Based on this information, we estimated annual rattan cane harvesting and floater log cutting in each village and then evaluated the impact of log cutting to primary forests and LLNP forest conservation efforts.

Potential impacts of cane harvesting on forest structure were assessed by monitoring the effect of cane removal on supporting vegetation of the permanently marked rattan plants in both Moa and Au from 1996 to 2000. Specifically, we recorded any evidence of damage to adjacent trees and tree cutting to extract cane that could not be pulled down around the marked plants and the number of natural and anthropogenic tree falls on the transects.

5) develop a model and guidelines for sustained yield *C. zollingeri* management in natural forests that balances local economic concerns with the conservation of biological diversity.

An attempt at interdisciplinary synthesis based upon the empirical fieldwork in LLNP comprised the final stage of the project. We developed guidelines for sustained-yield management and monitoring of *C. zollingeri* and initially sought to test the applicability of the approach to another major rattan producing area in Central Sulawesi, Morowali Nature Preserve. However, the eruption of widespread violence between Muslims and Christians in 1999 precluded undertaking this work. However, we identified key ecological attributes and social, economic, marketing and institutional conditions necessary for sustained-yield management of rattan in and around protected areas. These findings and recommended monitoring methods were presented at a workshop to Government of Indonesia (Forestry, Agriculture, Estate Crops, etc.) and nongovernmental conservation personnel in August 2000 in Palu, Central Sulawesi and at an UN FAO sponsored consultation on rattan in December 2000.

Results

Economically Important Rattan Species

The rattan flora of central Sulawesi is diverse, but poorly known. The wide range of environmental conditions (e.g., extreme micro-topographic variability, lavational gradients, and

variety of geological substrates), in conjunction with Sulawesi's long isolation from other islands, and the inter-island isolation of mountain masses has given rise to a rich and unique rattan flora. Unfortunately, there has been little systematic sampling of rattan in the region. There is no guide to Sulawesi rattan flora and there is a great deal of uncertainty regarding the identity and classification of many rattan species. Table 1 summarizes economically important rattan species recorded in southern LLNP, their primary use(s), whether they are marketed (i.e., sold for cash income) and/or used domestically within the household, and their value.

Table 1: Economically Important Rattan in the Southern Lore Lindu Region

Species	Indonesian Name	Use, Market and Value (1996)
Calamus leptostachys Becc. ex Heyne	togisi	binding; household and sale (Rp 2,500/100 split canes)
Calamus leiocaulis Becc. ex Heyne	ronti	binding; household and sale (Rp 2,500/100 split canes)
C. ornatus var. *celebicus* Becc.	lambang	secondary commercial cane (Rp 50-150/kg) fruits; household
C. zollingeri Becc.	batang batu	premier commercial cane (Rp 100-350/kg) food (shoots); household & sale (Rp 100/shoot)
C. ahlidurii (?) & *C. macrosphaerica*	batang lelut	premier commercial cane, but less frequently collected (Rp 100-350/kg)
Daemonorops robusta Warb.	noko	roofing; household & sale (Rp 200/shingle) food (shoots); household & sale (Rp 100/shoot)
Daemonorops sarasinorum (Warb.) Becc.	batang lelut	premier commercial cane, but less frequently collected (Rp 100-350/kg)

Prior to the development of the large-diameter cane export industry in the 1980s, the most important rattan was togisi (*C. leptostachys*). *Calamus leptostachys* was traditionally used for a wide variety of binding and basketry purposes; the cane is very strong (in whole or split form), supple, durable and long (to 100+ m). While canes of *C. leptostachys* are still used for binding (e.g., clotheslines, basketry, horse-packing and bridge construction), their use is increasingly being replaced by nylon rope, plastic baskets, and steel cable.

Since the advent of cane extraction for the furniture industry, the most important rattans have been the batang trade group. *Calamus zollingeri* is the most important and wide ranging of these species. At higher elevations (i.e., in montane forests), *C. zollingeri* is replaced by other rattans traded under the batang name. The identity of montane batang remains uncertain. It appears to include *Daemonorops sarasinorum*, *C. macrosphaerica*, and possibly *C. ahlidurii*, a named, but as yet undescribed rattan. Voucher specimens of all rattans encountered during fieldwork are deposited in the Herbarium at University Tadulako, Bogoriense, and Kew, England.

Socioeconomic Role and Importance of Rattan

The role and importance of rattan in household, village and provincial economies is dynamic and variable. At the household level, the role of rattan varies with household life stage and access to alternative livelihood activities (especially access to sawah, ladangs and kebuns) and all of these factors typically vary from village to village.

In the forest villages of Moa and Au 85% and 58% of households surveyed, respectively, relied upon rattan collection as a source of income in 1998 (Table 2). In the case of Moa, this percentage remained largely unchanged from 1996 when 90% of households were involved in rattan collection. Not surprisingly, the villages of Gimpu and Tomua, which are located further from the forest and have a wider range of livelihood options, rely less on rattan resources, only 19 and 7% of households, respectively, collected or traded rattan in 1998.

Table 2: Rattan Cane Harvesting and Cultivation Interest in Four Villages

Rattan Collection and Cultivation Interest (%) by Village (1998)

Activity	Moa (n=41)	Au (n=12)	Tomua (n=30)	Gimpu (n=31)
Rattan collection By households	85 %	58 %	7 %	19 %
Households interested in cultivating rattan	93 %	0 %	13 %	26 %

The socioeconomic importance of rattan also arises from its seasonal role as a source of income for Christmas celebrations and presents. Monthly rattan production figures from Moa and Au over the course of two years revealed that cane collection peaks in December; residents report that rattan gathering is the standard means for procuring cash for the holidays (pers. com.).

Less than 15 years ago, large-scale commercial collection of rattan canes did not exist. While a number of rattan species have been utilized for a wide variety of domestic purposes for generations, *C. zollingeri* was not one of them; it was simply not collected. With the arrival of market demand for furniture-diameter canes in the 1980s, commercial rattan collection and transport (i.e., floating cane down the Lariang River) became a major player in household, village, and provincial economies. Not only did a large percentage of forest and near-forest dwelling households begin to collect rattan, the trade attracted immigrants from other areas of Sulawesi. For example, 10% of Moa households surveyed in 1996 reported moving to the village within the previous decade specifically to collect rattan. In fact, recent immigrants have displaced many traditional residents of Gimpu and Tomua. These formerly homogenous Uma communities are now ethnically, culturally, and religiously diverse, and many Uma have sold their land and homes and moved to isolated communities in the forests south of LLNP.

Recent growth and development in Gimpu, Tomua, and other villages located along the Palu to Gimpu road, reflects, in part, the lucrative rattan trade. Not surprisingly, the rattan trade is dominated by outside economic interests, particularly Chinese and Bugis. Ethnic Chinese and Bugis (an ethnic group from South Sulawesi) have long been active in trade and commerce and now dominate local and regional trade and investment in many sectors throughout Indonesia.

The role and importance of rattan at the household level varies with household access to alternative livelihood sources. Households who lack access as either owners or tenants to irrigated and/or upland rice production must purchase their household rice needs (or consume less desirable foods such as corn, cassava, etc.). The former is an expensive proposition given the distance of Moa (25 km) and other communities from roads and major rice producing areas. In Moa, 70% of village households surveyed in 1996 had access to irrigated rice production, but household rice self-sufficiency averaged only 7.9 months per year among those with access to

rice. Furthermore, half of the rice-growing households produced 6 months or less of their annual household rice needs (Table 3).

Table 3: Livelihood Profile of Moa Households in 1996

Livelihood activity	Percent or Amount (n=20)
Cultivate Rice	
Households cultivating irrigated rice (%) (as owner or tenant)	70 %
Mean # Months Household Rice Self-Sufficiency	7.9 months (+/- 3.5) (range 2-12+)
Households cultivating upland rice (%)	25 %
Mean # Months Household Rice Self-Sufficiency	5.8 months (+/- 3.9) (range 2-12)
Total irrigated and upland rice (%)	95 %
Mean # Months Household Rice Self-Sufficiency (all households)	7 months (+/- 3.9) (range 0-12)
Cultivate Perennial Crops	
Cacao planted	75 %
producing (as of October 1996)	20 % (27% of planted)
Yield (mean)	114 kg (+/-125) (range 30-300)
Coffee planted	85 %
producing (as of October 1996)	70 % (82% of planted)
Yield (mean)	110 kg (+/-207) (range 3-800)
Collect Rattan	90 %

Other livelihood activities reported: gold panning (2), guest house (1), coconut oil (1), collect other forest products (1), carpenter (1).

The ability to purchase rice or other household staples requires income. For the past decade, collecting rattan has provided the primary means for resource poor household to meet their food and other staple needs. The relationship between household rice self-sufficiency and reliance upon rattan and other forest product collecting is well established. For example, rattan harvesting was inversely related to household rice self-sufficiency and was an important income source for all households in times of emergency or special needs (e.g., crop failures, funerals, weddings, etc.) in the Philippines (Siebert and Belsky, 1985). Household income needs can be met through other means, particularly the cultivation of perennial cash crops, but the year-round availability of rattan on public lands continues to provide many, especially poorer households, with irreplaceable income and insurance.

The economic role and importance of rattan to households and villages in southern LLNP may be changing. First, the time and effort required to gather and transport rattan appears to limit harvesting to areas less than 10 km from rivers. The extent of cane harvesting and its environmental effects may be approaching the limit of viable cane transport. Unless cane prices increase significantly or the market for perennial cash crops collapses, cane collection may decline in relative importance as available supplies are exhausted.

Secondly, the recent Indonesian economic decline and wider Asian recession have adversely affected the rattan furniture industry. Domestic and export demand for rattan furniture

has declined, at least temporarily, and many Indonesian furniture businesses lack operating capital (Sumardjo, rattan furniture manufacturer, pers. com.). The market prices for coffee and cacao have also fluctuated dramatically (reaching highs immediately after the 1997 devaluation of the Indonesian Rupiah, but subsequently declining). Current coffee and cacao prices are near record lows.

Rattan Abundance, Distribution and Cane Growth Rates

Calamus zollingeri is abundant and widely distributed throughout low and mid-elevation slopes in LLNP (Table 4) and occurs to approximately 1100m elevation where it is replaced by montane batang species. Populations of *C. zollingeri* averaged 52 genets with 1116 ramets per hectare in Moa and 78 genets with 1777 ramets per hectare in Au. Populations of *D. sarasinorum, C. macrosphaerica* and *C. ahlidurii* (?) were lower than *C. zollingeri*, but abundant in both Moa and Au forests at higher elevations.

Table 4: The Abundance of Rattan Genets and Ramets in the Southern Lore Lindu Region

	Mean number/ha			
	Genets		Ramets	
species	Moa	Au	Moa	Au
Batang trade complex	54	76	1184	1330
Calamus zollingeri	52	78	1116	1376
Calamus ahlidurii (?), *Calamus macrosphaerica* *Daemonorops sarasinorum*	14	10	385	148
Calamus leptostachys	13	40	2754	8248
Calamus ornatus[1] var. *celebicus*	32	96	-	-
Daemonorops robusta	5	16	1567	4686

1 - solitary species (genets = ramets)

Calamus zollingeri has been repeatedly harvested in the forests near Moa and Au since the 1980s. Monitoring of permanently marked *C. zollingeri* plants revealed that an average of 3.5 (+/- 4.3) and 0.7 (+/- 1.5) new ramets/genet were produced in Moa and Au, respectively, during the first year following cane harvesting. Rattan are also capable of rapid cane growth. Cane elongation rates averaged 4.7 (+/- 3.7) m/cane in Moa and 2.5 (+/- 2.9) m/cane in Au per year following cane harvesting (Table 5). In Moa, 32% of marked plants had been harvested again within the year, while 41% had been harvested again in Au. Why *C. zollingeri* ramet production and growth differ between Moa and Au is unclear. The two sites are less than 15 km apart, have the same forest type and are at the same elevation. The sites may differ due to more intense cane harvesting in Au and site-specific micro-climatic conditions (e.g., cacao production was reportedly much reduced in Au during the severe "El Nino" drought of 1997, but little affected in Moa; per. com.).

Table 5: Calamus zollingeri Ramet Production and Cane Growth 1 Year after Harvesting

	Mean Ramet Production and Cane Growth (m) after 1 Year	
	Moa	Au
new ramets/plant	3.5 (+/- 4.3)	0.7 (+/- 1.5)
cane elongation (m)	4.7 (+/-3.7)	2.5 (+/- 2.9)
mean cane length (m)	22.3	17

The batang species (*C. zollingeri, C. macrosphaerica, C. ahlidurii* (?) and *D. sarasinorum*) are marketed interchangeably (Rp 350/kg at roadside in 1997; Rp 500-800 in 1998) and have similar growth and reproductive characteristics. *Calamus zollingeri* produces clusters of canes and displays vigorous rhizotomous growth (up to 50 ramets/genet and vegetative sprouts up to 20 m from parent plants; pers. obs.). This growth pattern suggests that populations of *C. zollingeri* may be clonal over large areas.

Cultivation and Management of *C. zollingeri*

1) Survival and growth of cultivated *C. zollingeri* intercropped in coffee and cacao farms

Over 96 % of wild *C. zollingeri* seeds germinated, survived transplanting into seedling bags, and grew to transplanting size (i.e., 25 cm height with 2-3 leaves) under controlled conditions. In contrast, 61% of *C. zollingeri* seedlings were successfully raised to transplanting size using vegetative cuttings in the village nursery. Nevertheless, seedlings from cuttings grew an average of 12.6 cm and produced 2.5 new leaves per plant after 20 months (Table 6). Monthly monitoring of seedling growth and root development suggests that *C. zollingeri* are suitable for transplanting after 12 months whether produced from cuttings or seeds.

Table 6: Survival and growth of *Calamus zollingeri* seeds and vegetative cuttings after 20 months

Characteristic	Seeds	Vegetative Cuttings
Survival (%)	96	61
Seedling height (cm)	25.5 (+/- 5.1)	12.6 (+/- 6.4)
New leaves produced	2.5 (+/- 0.8)	2.5 (+/- 1.2)
Total available PAR (%)	n/a	33

The seedlings required no additional water during rainy seasons, but were watered twice daily during dry periods. Light intensity in the nursery averaged approximately 33% of total available PAR. The primary source of seedling mortality in the nursery (i.e., 39%) was caused by mice feeding on meristems during the rainy season.

Transplanted *C. zollingeri* seedlings exhibited high survival rates and vigorous growth under both farm and forest conditions (Table 7). Overall, 96% of *C. zollingeri* seedlings survived eight months after transplanting, including one dry period. Seedling height growth averaged over 12 cm per plant and an average of 0.8 new leaves were produced per seedling. Seedling survival rates did not vary significantly between sites, nor did seedling growth or the production of new leaves (Table 7). Mean seedling growth varied from 10.7 to 14.7 cm, while the number of new leaves produced varied from 0.3 to 1.7 in the four transplant sites.

Table 7: *Calamus zollingeri* seedling survival, growth, leaf production rates, light intensity and tree fall effects 8 months after transplanting in coffee and cacao agroforests

	Transplant Sites (mean +/- Std. Dev.)				
	A Primary forest	B Farm (20yr canopy)	C Farm (20yr canopy)	D Farm (primary canopy)	Mean all sites
Seedling					
Survival (%)	92	94	100	98	96
Growth (cm)	14.0 (+/-12.9)	14.7 (+/-12.2)	11.4 (+/-11.5)	10.7 (+/-10.1)	12.7
New Leaves Produced	0.3 (+/-0.7)	0.6 (+/-0.9)	1.7 (+/-1.4)	0.6 (+/-0.8)	0.8
Total Available PAR (%)	4	11	10	2	6.8
Plants impacts by Branch/tree falls (%)	4	8	1	3	4

The most important variables affecting seedling survival and growth were soil drainage and branch or tree fall-induced mortality (Table 8). Seedlings in poorly drained sites exhibited average growth rates of 2.8 cm, did not produce new leaves, and suffered 18% mortality rates. Seedlings impacted by branch or tree falls grew an average of 5.0 cm, produced 0.1 new leaves and suffered 52% mortality rates. In contrast, all other *C. zollingeri* seedlings grew an average of 13.8 cm, produced 0.9 new leaves and suffered no mortality. These differences are all significant based on post-hoc Bonferroni ANOVA tests. While light is obviously essential to *C. zollingeri* seedling survival and growth, light intensity was only weakly related to seedling growth and new leaf production. Pearson Correlation relationships between PAR and seedling growth and new leaf production were 0.068 and 0.158, respectively. While wild *C. zollingeri* populations are significantly more abundant in high than low-light environments (Siebert, 1993), no significant relationships were observed between PAR levels and either seedling growth or leaf production rates in this study, notwithstanding the fact that individual seedling light levels ranged from to 0.3 to 97.3 % of total available PAR (i.e., from complete shade to full sun).

Table 8: Soil drainage and tree/branch fall effects on *Calamus zollingeri* seedling survival, growth and leaf production£ after 8 months in coffee and cacao agroforests

Sites§	Seedling growth (cm)	F	P	New leaves produced	F	P	Seedling mortality (%)
Poorly drained (n=11)	2.8 (+/-3.6)	9.02	0.003	0 (+/-0)	6.12	0.014	18 %
Tree/branch fall (n=29)	5.0 (+/-7.8)	13.11	0.000	0.1 (+/-0.4)	7.68	0.001	52 %
All other sites (n=363)	13.8 (+/-11.8)			0.9 (+/-1.1)			0 %

£ - F and P values reflect differences between poorly drained vs. all other sites and branch/tree fall vs. all other sites based on post-hoc Bonferroni ANOVA.
§ - three sites were both poorly drained and impacted by branch/tree falls.

Branch and tree falls appear to be another important determinant of *C. zollingeri* survival and growth. The percentage of seedlings affected by branch or tree falls varied from 1 to 8 % and fully 52% of impacted seedlings were killed (Table 8). Removal of dead branches could reduce damage to rattan and other crops. Indeed, branch/tree fall rates were lowest in intensively managed farms and highest in the primary forest and in a poorly maintained farm (Table 7).

Marketable rattan (i.e., greater than 10 m) may become available after about 12 years, at which time farmers expect to periodically extract canes from supporting trees with little adverse effects to their coffee or cacao, particularly where rattan is planted along farm perimeters (pers. com.). Moa farmers express interest in rattan cultivation as a means of diversifying perennial cash cropping systems, which they perceive to be subject to volatile market demand and price fluctuations. Intercropping *C. zollingeri* in coffee and cacao agroforests provides a means of intensifying traditional farming systems that is compatible with local livelihood interests.

Vegetative cuttings appear to offer a viable alternative to seeds for the cultivation of *C. zollingeri*. Vegetative cuttings of *C. zollingeri* are free, abundant, readily available within 2 km of village and farm transplant sites, and can be collected at any time of the year. Many farmers already produce coffee and cacao seedlings in small nurseries and would incur little additional expense to produce rattan. The high seedling mortality caused by mice could be reduced through use of locally available traps and/or the construction of nurseries near homes where cats and dogs may control mouse populations. Indeed, coffee and cacao seedlings are typically raised immediately adjacent to homes.

Rattan nurseries can be simple and inexpensive to construct. The nurseries in this study measured 4 x 8 m and were constructed of bamboo poles, coconut palm thatch, and split bamboo fencing to exclude domestic animals. Expenditures for nursery construction and seedling transplanting totaled approximately US $100 (Rp 225,000 @ Rp 7,500 daily wage rate for 30 days nursery construction and seedling collection and transport at $1 = Rp 2,200, October 1996). In addition, a small daily wage was paid to a local resident to maintain the seedlings.

2) Effects of cane harvesting on wild *C. zollingeri*

The long-term implications of intensive cane harvesting on *C. zollingeri* populations have yet to be completely analyzed; only a portion of the data gathered is presented here. Evidence of excessive cane harvesting is widespread throughout southern LLNP and marketable supplies of rattan (i.e., canes great than 10m in length) have become increasingly scarce. In 1995, Moa collectors reported gathering all *C. zollingeri* canes within 1-3 km of the village on low and mid-elevation slopes. By 1997 collectors typically traveled 6 to 10 km into LLNP and had shifted, in part, to higher elevations and the collection of other batang species.

The potential that intensive cane harvesting will lead to the extermination of rattan populations varies with species-specific growth and reproductive characteristics (Peters, 1996). Most large-diameter rattan, unlike *C. zollingeri*, are solitary and reproduce via sexual means only; when canes are cut, the plants die (Dransfield and Manokaran, 1994). Intensive cane harvesting has resulted in the extermination of *C. manan* and other solitary rattans throughout much of Asia (Dransfield and Manokaran, 1994).

Calamus zollingeri is abundant and widely distributed throughout lower montane forests and is one of the most common rattans in and around LLNP. At approximately 1150 m it is replaced, as noted, by other species marketed under the trade name "batang". We recorded an average of 149 *C. zollingeri* genets with 1431 ramets and 66 canes of harvestable length (i.e., > 10 m length) per hectare in forests below 1150 m when first sampling the case study watershed in 1996 (Table 9). In 2000 we found an average of 143 genets with 1595 ramets and 46 canes per hectare in the same watershed. Populations of *C. zollingeri* exhibited extremely patchy distribution with massive plants (i.e., greater than 20 ramets) dominating the understory and canopy along some portions of the transects, while no *C. zollingeri* were observed in other areas.

Table 9: Differences in *Calamus zollingeri* Genet and Ramet Populations over 4 Years

	Mean number per ha (+/- std.dev.) based on 100 m^2 sample plots along 3 random transects	
	1996 (n = 205)	2000 (n= 150)
Genets	149 (+/- 103)	143 (+/- 118)
Ramets	1431 (+/- 1402)	1595 (+/- 1437)
Harvestable Canes (> 10 m)	66 (+/- 120)	46 (+/- 84)

Calamus zollingeri occurred in both high-light (e.g., canopy gaps) and densely shaded environments, but was absent in poorly drained or seasonally flooded sites. Finally, we observed no evidence of mortality or dieback to *C. zollingeri* genets, irrespective of the frequency or number of canes harvested. For example, on marked plants we recorded no cane harvesting-induced mortality even though approximately 33% were harvested each year and in 2000 canes were typically cut upon reaching 10 m in length.

On marked *C. zollingeri* plants we found that the mean number of ramets/genet was significantly greater in 2000 than in 1996 (Table 3). However, the mean number of harvestable ramets/genet (i.e., canes > 10 m length) was significantly lower in 2000 than in 1996, as was the mean length of harvestable cane and the total amount (i.e., length) of harvestable cane. In fact, in 2000 there was less than half the amount of harvestable cane as recorded on the same plants in 1996. The impact of intensive cane harvesting is readily apparent when comparing cane length distribution classes in 1996 with 2000 (Table 11). For example, we recorded 37 canes greater than 20 m in length on marked *C. zollingeri* in 1996, but only three canes greater than 20 m on the same plants four years later.

Table 10: *Calamus zollingeri* Ramet Production and Growth over 4 Years on Marked Plants

	Marked Plants (n = 74)	
	1996	2000
Mean number ramets/genet	12.4**	15.6**
Mean number harvestable ramets/genet (canes > 10m)	1.0*	0.7*
Mean ramet (cane) length	22.4 m**	11.4 m**
Mean length harvestable ramets (canes > 10m)	26.0 m **	17.3 m**
Total length harvestable cane (all plants)	1953 m	880 m

** means significantly different at P=0.01 based on paired sample t-test.
* means significantly different at P=0.05 based on paired sample t-test.

Table 11: Distribution of cane lengths on marked plants in 1996 and 2000

Cane length classes	number 1996	number 2000
<10 m	19	69
10-20 m	38	48
20-30 m	23	3
30-40 m	7	0
>40 m	7	0

These data have several important implications for the management of wild rattan. First, repeated cane harvesting (i.e., cutting canes when great than 10 m) may stimulate production of new ramets. Indeed, we recorded an average of 3.5 new ramets produced per genet and 4.7 m of cane growth on marked plants one year after harvesting. The production of new ramets and rapid cane growth suggests that large numbers of canes could continue to be available in the future. Secondly, cane harvesting has significantly reduced mean cane length, which, in turn, reduces returns to labor and requires collectors to travel further into the forest. Thirdly, the cutting of all mature ramets may preclude sexual reproduction. This is supported by the absence of flowering and fruiting on marked rattan during two years of bi-weekly monitoring. While *C. zollingeri* is clearly capable of vigorous vegetative growth, sexual reproduction is important for maintaining species vigor and diversity over the long-term. As noted previously, ramet production and cane elongation rates are lower in Au, where cane harvesting has been more intense, than in Moa (Table 5). This suggests that vegetative reproductive capabilities and cane growth may be adversely affected by intensive harvesting.

The general resilience of plant populations, such as rattan, is explained in part by their frequently smaller area requirements, longer life spans, and greater reproductive potentials than other organisms (Laurance, 1997). When these characteristics are considered along with the clustering and vegetative propagation potentials of *C. zollingeri*, and the fact that lethal harvesting practices have not been observed, present cane harvesting would not appear to threaten the biological existence of the species (i.e., genets). Nevertheless, supplies of marketable-sized cane (i.e., ramets) may be exhausted, at least temporarily (i.e., until new ramets are produced and allowed to grow to commercial lengths).

Calamus zollingeri flower and fruit on an irregular basis and even prior to cane collecting were reportedly not observed in large quantities (rattan collectors, pers. com.). Two years of phenological monitoring revealed that only three mature *C. zollingeri* produced fruit between 1996 and 1998. This may reflect intense harvesting pressures and thus a lack of mature reproductive ramets or the effects of a strong "El Nino". *Calamus zollingeri* fruits are small (7-9 mm in diameter), extremely bitter, and reportedly rarely eaten by birds or mammals (rattan collectors, pers. comm.).

3) Effects of cane harvesting on ecosystem nutrients

Nutrient allocation in *C. zollingeri* appears to follow the same pattern observed in most tropical tree species. Concentrations of macronutrients, with the exception of P, are significantly greater in leaf than in cane tissues and no significant differences in seasonal nutrient allocations were observed (Table 12). Rattan, like most tropical trees, do not exhibit seasonal leaf senescence, but shed leaves periodically throughout the year. Thus, it is not surprising that leaf and cane nutrient concentrations would remain largely unchanged during the year.

Nutrient removals through rattan harvesting could potentially affect ecosystem nutrient stores via direct loss when canes are extracted and indirect loss through runoff and leaching following harvesting. Tropical forests produce tremendous amounts of biomass (i.e., 300 - 500 t/ha dry weight) and nutrient losses associated with selective timber harvesting average ca 2 to 5 percent of total aboveground biomass (Bruijnzeel & Critchley, 1994). Lianas (all species, including rattans) seldom represent more than 5 percent of total above-ground biomass in primary tropical forests and typically have 5 to 20 percent of that biomass in foliage, compared to only 1 to 2 percent in the case of trees (Hegarty & Caballe, 1991). When rattan is harvested, leaves and leaf sheaths are left on the forest floor, only mature canes (*i.e.*, those 10 m or longer) are extracted. Thus, direct nutrient losses associated with harvesting cane from a single rattan species are unlikely to adversely affect ecosystem nutrient stocks and are probably replenished through wet and dry deposition, N-fixation, and weathering (Bruenig, 1996; Richards, 1996). Atmospheric nutrient deposition can be substantial; Crowther (1987), for example, recorded annual additions of 36.1 kg/ha Ca, 3.4 kg/ha Mg and 3.7 kg/ha K through precipitation alone in a Malaysian forest.

Table 12. Mean (+/- SD) and significance of difference in *Calamus zollingeri* leaf and cane nutrient concentrations during dry and wet seasons based on a 2-way Bonferonni protected ANOVA following log (x +1) transformation.

	Plant Part and Season (Dry or Wet)				Comparison &	
Nutrient	1 - Leaf dry	2 - Cane dry	3 - Leaf wet	4 - Cane wet	Adjusted *P*	
Cu (mg/Kg)	7.64 (1.41)	13.16 (1.90)	6.66 (2.23)	8.56 (4.18)	ns	
Ni (mg/Kg)	5.06 (2.10)	7.38 (1.62)	3.48 (1.25)	5.36 (3.11)	ns	
Zn (mg/Kg)	12.56 (1.26)	26.34 (5.60)	15.56 (5.88)	105.80 (54.81)	2 vs. 4	0.004
					3 vs. 4	<0.001
Al (mg/Kg)	18.92 (8.60)	12.74 (4.96)	23.14 (7.28)	53.92 (63.57)	ns	
Fe (mg/Kg)	87.44 (26.21)	141.70 (17.88)	57.84 (11.64)	109.38 (86.56)	ns	
B (mg/Kg)	7.04 (1.32)	2.96 (0.23)	5.82 (1.54)	2.48 (0.43)	1 vs. 2	<0.001
					3 vs. 4	<0.001
Pb (mg/Kg)	3.72 (2.20)	7.70 (2.42)	0.28 (0.63)	0.48 (0.66)	1 vs. 3	0.001
					2 vs. 4	<0.001
Mn (mg/Kg)	56.74 (74.41)	9.12 (5.09)	134.20 (20.64)	698.42 (529.82)	1 vs. 2	0.05
					1 vs. 3	0.05
					2 vs. 4	<0.001
					3 vs. 4	0.039
Ca (%)	0.44 (0.16)	0.12 (0.01)	0.50 (0.13)	0.14 (0.02)	1 vs. 2	<0.001
					3 vs. 4	<0.001
Mg (%)	0.28 (0.06)	0.04 (0.00)	0.30 (0.05)	0.05 (0.01)	1 vs. 2	<0.001
					3 vs. 4	<0.001
K (%)	0.61 (0.12)	0.42 (0.05)	0.53 (0.08)	0.12 (0.03)	1 vs. 2	0.007
					2 vs. 4	<0.001
					3 vs. 4	<0.001
P (%)	0.11 (0.02)	0.06 (0.01)	0.12 (0.03)	0.14 (0.05)	2 vs. 4	0.005
N (%)	1.64 (0.13)	0.31 (0.02)	1.58 (0.12)	0.47 (0.13)	1 vs. 2	<0.001
					3 vs. 4	<0.001

Indirect nutrient losses from cane harvesting are unlikely to be large because leaf litter and plant root masses are not disturbed and the forest canopy is rarely opened when cane are extracted (i.e., canes are cut at the base and pulled from supporting trees). Bruijnzeel & Critchley (1994) note that leaching losses associated with logging tend to occur only where root mats and

litter are disturbed by heavy machinery and that leaching increases when canopy gap sizes exceed 200 - 550 m^2. Even when trees are cut to gather rattan, gaps rarely exceed 200 m^2 (pers. obs.).

The apparently insignificant nutrient losses associated with *C. zollingeri* cane extraction suggest that repeated harvesting of wild rattan will not adversely affect ecosystems nutrient stocks. Nutrient losses associated with rattan grown in intensive plantations warrants further study, as does seasonal nutrient allocation to foliage and canes in edaphically stressed environments such as ultramafic and limestone formations.

4) Effects of cane harvesting on forest structure

Lianas, including rattan, link the forest floor to the canopy and canopy trees to one another throughout the humid tropics (Hegarty and Caballe, 1991; Putz, 1991). The physical connectivity provided by lianas may be of ecological significance for several reasons. First, harvesting cane could damage the supporting trees upon which rattan grow. Second, tree fall gap sizes may be impacted, that is larger gaps may be created when liana-bound trees fall. Natural tree fall gaps normally occupy 5 to 15% of the area in a primary forest and are important in plant regeneration and growth (Peters, 1996). Indeed, cutting lianas, including rattan, is recommended prior to logging throughout Southeast Asia (Appanah and Putz, 1984).

Rattan cane harvesting is a manual activity. Canes are cut at the base and then pulled down from supporting vegetation. Cane harvesting appears to have little effect on supporting trees or on understory vegetation that may be struck when canes fall to the ground (i.e., little or no damage was observed to other vegetation immediately after harvesting and no effects were evident in subsequent years around marked plants).

On the other hand, supporting trees are occasionally felled when canes cannot be pulled down. In 1996, there was no evidence of tree felling to gather rattan along the transects in Moa or Au. One year later (1997), an average of 0.3 tree/ha had been felled to gather rattan in Moa and 3.0 tree/ha in Au (Table 13). According to rattan collectors, tree felling increased due to the scarcity of easily extracted, large-diameter cane near villages. In Moa, collectors reported that the depletion of marketable cane confronts them with two options, either traveling 6-10 km into LLNP forests where canes have not yet been harvested or felling trees from which rattan can not be pulled, canes that in the past simply would have been left alone due to the labor required to extract them. By 1998 and thereafter, no additional tree felling to gather cane was observed, reportedly because all harvestable cane had been extracted (rattan collectors, pers. com.).

Table 13: Natural Tree Falls and Tree Felling to Gather Rattan

	Mean number/ha	
	Moa	Au
1996		
Natural tree fall gaps	16	16
Trees cut for rattan	0	0
1997		
New natural tree falls	2.3	0.3
Trees cut for rattan	0.3	3.0

Tree falls, both natural and to extract cane, can affect residual rattan plants. In the forests of Moa, for example, natural tree falls crushed 6.6% of the marked rattan plants and resulted in the death of 2.8% of the plants over a two-year period. Trees cut to harvest rattan crushed an

additional 1.9% of marked plants during the same period, all of which were killed. In Au, three times as many rattan were impacted by cut trees than by natural tree falls and rattan mortality increased 2.5 times (Table 14).

Table 14: Effect of Natural Tree Falls and Harvested Trees on *Calamus zollingeri*

	Percentage of *C. zollingeri* impacted over two years		
Impact	Moa (n=106)	Au (n=48)	Total (n=154)
Natural Tree Falls			
Rattan crushed	6.6%	2.1%	5.2%
Rattan killed	2.8% (43%)	2.1% (100%)	2.6% (50%)
Trees Cut to Harvest Rattan			
Rattan crushed	1.9%	6.3%	3.3%
Rattan killed	1.9% (100%)	4.2% (67%)	2.6% (80%)
Total Natural & Enhanced Tree Falls	8.5%	8.4%	8.4%
Total Natural & Enhanced Mortality	4.7%	6.3%	5.2%

Tree fall gaps comprised an average of 16% of the sample plots in both Moa and Au in 1996. Whether natural tree fall gap sizes are affected by eliminating large *C. zollingeri* cane from forest canopies is not known. Potentially, mean gap sizes could decline if trees were not bound together by large lianas. However, many other large-diameter lianas that are not collected would remain even if all *C. zollingeri* were removed. This includes such locally prominent and abundant rattan as *C. ornatus* and *D. robusta.*

5) Effects of cutting logs to float rattan to market

Cutting small trees to float bundles of rattan cane to market is widespread and purported to adversely affect primary forests and biodiversity conservation in LLNP (Schweithelm, et al. 1992; BCN, 1996). We monitored rattan cane harvesting, tree species used as floater logs, and the locations and volume of floater log cutting in Moa and Au for two years. During this period, an average of 135 and 100 tons of commercial rattan cane, primarily *C. zollingeri*, was harvested annually from the two villages, respectively (Table 15). Floating cane to market required approximately 2350 and 1667 logs (each 3 m in length and 15-20 cm in diameter) or about 1175 and 834 trees annually in Moa and Au. Eight tree species were regularly used as floater logs and all were lightweight, fast-growing, pioneer species (Table 16). Floater logs were harvested from fallowed shifting cultivation fields and naturally disturbed riparian flood plains. Over the two-year study period, there was little floater log cutting in primary forests either inside or outside of LLNP. The use of early successional tree species to float rattan to market does not appear to adversely affect primary forests or protected area management in this region.

Table 15: Rattan Cane Production and Floater Log Cutting in Two Villages

	Annual Amount Harvested[1]		
	Rattan (tons)	Floater logs[2]	Trees[3]
Moa	135	2350	1175
Au	100	1667	834

1 - mean of two years (10/96 - 9/98).
2 - assuming each 3 m log floats a 50 kg bundle of cane.
3 - approximate, assuming two floater logs are cut from each tree.

Table 16: Tree Species Used to Float Rattan

Species	Local Name (Uma)
Artocarpus teysmanni Miq.	tea uruh
Evodia latifolia D.C.	ki hio
Grewia multiflora Juss.	wokeh
Horsfieldia sp.	laru
Macaranga hispida Muell.Arg.	meapoh
Macaranga triloba (L.) Muell.Arg.	lengkoba
Pterospermum celebicum Miq.	entorodeh
Trema orientalis (L.) Blume	wulajah

Sustainable Rattan Management Monitoring and Methods

One of the challenges in assessing ecological sustainability is determining and establishing monitoring protocols for the vast array of possible direct and indirect biological effects. Principal effects associated with rattan cane harvesting at the species level include: effects to genets, ramets, and ramet production and growth; at the ecosystem level: effects to ecosystem nutrients, forest structure, forest succession, and vertebrate food resource availability; and indirect effects associated with transporting cane to market and incidental hunting of birds and mammals. While assertions by biologists that it is impossible to reliably and comprehensively ascertain all possible ecological effects is undoubtedly true, continued rattan harvesting necessitates that efforts be made to monitor and manage cane harvesting. Table 17 summarizes the primary direct and indirect effects associated with *C. zollingeri* cane harvesting in Central Sulawesi and the methods used to assess and monitor them in this study. These criteria should be relevant to monitoring rattan cane harvesting effects throughout the range of these economically important plants.

A narrow consideration of economic costs and benefits suggests that returns from rattan gathering and cultivation compare poorly with perennial cash crop alternatives. However, it is important to remember that rattan is a primary or secondary source of cash income for tens of thousands of forest-dwelling people throughout Southeast Asia (DeBeer and McDermott, 1989) and is an irreplaceable source of emergency income for thousands more (Siebert and Belsky, 1985). Furthermore, rattan gathering and cultivation by smallholders in either swidden fallows or as an intercrop in traditional agroforestry systems provides important social and environmental benefits that tend to be ignored in narrow cost/benefit analyses. Foremost among these benefits are: 1) reduced economic risk due to less dependence upon volatile coffee and cacao markets; 2) potential to increase total returns; 3) reduced insect and disease infestation rates that may result

from greater species and structural diversity; and 4) maintenance of high levels of biological diversity and thus at least partial compatibility with biodiversity conservation interests.

Table 17: Important Potential Effects of Rattan Cane Harvesting and Monitoring Methods

Potential Effect	Monitoring Methods
Species-level	
Genet survival	resample permanently marked plants
Genet population structure }	resample permanently marked plants &
Cane (i.e., ramet) production}	replicated sampling of random transects
Cane growth	"
Ecosystem-level	
Nutrient stocks	determine nutrients in foliage and canes & volume cane extracted/unit area
Forest structure	long-term monitoring of sample plots & plants
Forest succession & composition	"
Understory trampling	"
Vertebrate food resources	biweekly sampling of marked plants
Invertebrate use	"
Other	
Cane transport (floater logs)	determine weight of rattan extracted, tree species and volume used as floater logs, and location trees extracted
Hunting	not investigated

Given the relatively low financial returns from wild rattan harvesting and long period of yield deferral when cultivating large-diameter canes, significant private investment in rattan management or cultivation is unlikely without outside (i.e., non-governmental, state or international) subsidies. Taylor and Zabin (2000) argue that support of community resource management in natural forests should be viewed not as a subsidy, but rather as payment for desired goods and services (e.g., carbon sequestration, functional watersheds, and biodiversity conservation) provided by intact forests. This approach could be broadened to include compensating people who are denied access to historic resources due to the establishment of protected areas. Targeted external funding of this sort could provide financial incentives for small farmers and rattan collectors to cultivate and manage rattan in and around protected areas. Increased returns from rattan harvesting might also be realized through green certification schemes as advocated by the Rainforest Alliance and as have been granted to timber harvested in certifiably sustainable ways.

Impact Relevance and Technology Transfer

This project enhanced the research and conservation management capabilities of The Nature Conservancy, University Tadulako, Herbarium Bogoriense, and the Directorate General of Forest Protection and Nature Conservation (PHPA). Specifically, the project: 1) improved ecological and social science research skills among participating personnel and students; 2) developed analytical techniques for the conservation and sustainable management of potentially threatened plant resources; and 3) generated a methodological approach that seeks to balance biodiversity conservation, protected areas management and the economic needs of local people. Several Indonesian students and professionals were supported by the project. The Nature Conservancy, Herbarium Bogoriense, University Tadulako and PHPA are now better positioned to expand and apply research to forest management and conservation efforts.

The relevance of the project is best illustrated by The Nature Conservancy decision to redirect funding in support of rattan-based micro-enterprise development in LLNP (1996-98) and subsequent efforts to improve the productivity and sustainability of perennial cash crop production (both in part as a result of research findings. Project support of Ramadhanil Pitopang of University Tadulako may be particularly valuable over the long-term as it enhanced local individual and institutional capacities. Finally, the development of monitoring and management protocols for sustainable rattan harvesting and cultivation may be applied to other regions with rattan resources. This includes much of Southeast Asia, Southern China, moist tropical regions of South Asia and Africa and islands of the western Pacific.

Project Activities/Outputs

Publications:

Siebert, S.F. 2001. Sustainable harvesting of wild rattan: viable concept or ecological oxymoron? *Unasylva* 52:36-45.

Siebert, S.F. 2001. Nutrient levels in rattan (*Calamus zollingeri*) foliage and cane and implications for harvesting. *Biotropica* 33:361-363.

Siebert, S.F. 2001. Rattan Cane Harvesting. The Nature Conservancy Indonesia Program Information Sheet SP 7, Palu, Sulawesi Tengah, Indonesia. 2 pp.

Siebert, S.F. 2001. Tree cutting to float rattan to market: a threat to primary forests? *Journal of Bamboo and Rattan* (in press).

Siebert, S.F. 2001. Harvesting wild rattan: opportunities, constraints and monitoring methods. UNFAO Expert Consultation on Rattan Development. Conference Proceedings, FAO, Rome (in press).

Siebert, S.F. From shade to sun-grown perennial crops in Sulawesi, Indonesia: implications for biodiversity and soil fertility. *Biodiversity and Conservation* (accepted).

Siebert, S.F. 2000. Survival and growth of rattan intercropped with coffee and cacao in agroforests of Indonesia. *Agroforestry Systems* 50:95-102.

Siebert, S.F. 1999. Where there is no beer: *Arenga pinnata* and sagueir in Sulawesi, Indonesia. *Palms* 43:177-181.

Siebert, S.F. 1999. Village-level cultivation and management of *Calamus zollingeri* in Sulawesi. In: R. Bacilieri and S. Appanah (Eds.) Rattan Cultivation: Achievements, Problems and Prospects. CIRAD/FRIM, Malaysia. pp. 193-199.

Siebert, S.F. 1998. Rattan Use, Economics, Ecology, and Management in the Southern Lore Lindu National Park Region of Sulawesi, Indonesia. Final Report: Rattan Micro-Enterprise Component, BCN Project, The Nature Conservancy, Jakarta, Indonesia. 39 pp.

Siebert, S.F. 1997. Economically important rattans of Central Sulawesi, Indonesia. *Principes* 41(1):42-46.

Papers presented/meetings attended:

Siebert, S.F. Is Harvesting Wild Rattan Sustainable and Compatible with Biodiversity Conservation. Invited plenary paper submitted to the ASEAN Non-Timber Forest Products Conference, Manila, Philippines, September 16-19, 2001. (unable to attend).

Siebert, S.F. Harvesting Wild Rattan: Opportunities, Constraints and Monitoring Methods. Paper prepared for: Expert Consultation on Rattan Development. UNFAO, Rome, December 5-7, 2000.

Siebert, S.F. Full-Sun vs. Shade-Grown Cacao and Potential Biodiversity Implications in Indonesia. Poster presented at: Society for Conservation Biology Annual Symposium, Missoula, MT, June 9-12, 2000.

Siebert, S.F. Conservation vs. Development" Rattan Cane Harvesting and Protected Areas Management in Indonesia. Paper presented at: 8th International Symposium on Society and Resource Management, Bellingham, WA, June 17-22, 2000.

Belsky, J.M. and S.F. Siebert. Economic Crisis and Intensification of Cacao Cultivation in Indonesia: Implications for Food Security and Environmental Sustainability. Paper presented at: 8th International Symposium on Society and Resource Management, Bellingham, WA, June 17-22, 2000.

Siebert, S.F. and J.M. Belsky. Social and Ecological Risks of Sun-grown Cacao Cultivation in the Context of Indonesia's Economic Crisis. Paper presented at the ASA/CSSA/SSSA Annual Meeting. Salt Lake City, UT. Oct. 31 –Nov. 4, 1999.

Siebert, S.F. Sustainable Harvesting for Biodiversity Conservation? The Case of Rattan in Indonesia. Invited presentation, Cornell University. February 23, 1999.

Siebert, S.F. Elevational Distribution of Rattan in Sulawesi, Indonesia: A Preliminary Report. Poster presented at the Forest Canopies Conference, Selby Botanical Gardens, Sarasota, FL. November 5-7, 1998.

Siebert, S.F. Village-level Cultivation and Management of *Calamus zollingeri* in Sulawesi. Paper presented at the International Meeting of Experts-Rattan Cultivation: Achievements, Problems and Prospects. European Community, Cirad-Foret, FRIM, Royal Botanic Gardens Kew, Kuala Lumpur, Malaysia. May 12-14, 1998.

Siebert, S.F. Dilemmas in Sustainable Management of Non-Wood Forest Products. Paper presented the International Workshop on Sustainable Management of Non-Wood Forest Products. FRIM, Selangor, Malaysia. October 14-17, 1997.

Siebert, S.F. The Abundance and Distribution of Rattan in Sulawesi, Indonesia. Paper presented at the IUFRO All Division 5 Conference. Pullman, Washington. July 7-12, 1997.

Siebert, S.F. Light Preferences of Three Economically Important Lianas in the Old and New World Tropics. Poster presented at the Forest Canopies Conference, Selby Botanical Gardens, Sarasota, FL. November 9-12,1994.

Training:

1) Presented a half-day workshop on the cultivation and management of rattan resources in buffer zones of Lore-Lindu National Park. Sponsored by BAPPEDA and The Nature Conservancy, Program Indonesia, August, 2000. Attended by approximately 35 Government of Indonesia Dept. of Forestry, Agriculture and Estate Crops personnel and representatives of local nongovernmental conservation and development organizations (CARE, TNC).

2) Trained two University of Tadulako (Palu, Sulawesi) undergraduates in social science research methods and employed them to assist in conducting a social survey (1999).

3) Supported field research, establishment of herbarium collections and support staff of Drs. Ramadhanil Pitopang, University of Tadulako for two field seasons (2000 & 2001).

Project Productivity

We successfully accomplished all proposed project goals with the exception of testing the applicability of the sustained yield harvesting model in the Morowali Nature Preserve. This was not completed due to the eruption of widespread violence between Muslims and Christians throughout much of Central Sulawesi in 1999 (which continues at present). Involvement of Co-P.I Dr.. Omega in field research activities was also limited after 1998 for the same reason. Ramadhanil Pitopang, faculty at University of Tadulako in Palu, began research on rattan and tree

flora, and establishment of a university herbarium with support from the project in 2000 and 2001. The model and associated monitoring methods have been reviewed at several international conferences (including a UN FAO sponsored Expert Consultation on Rattan).

Several important, unanticipated activities were completed under the project. This included: 1) investigating biodiversity, biophysical and socioeconomic effects associated with the intensified, region-wide cultivation of perennial cash crops particularly cacao (*Theobroma cacao*); 2) supporting field research and herbarium establishment by Ramadhanil Pitopang of University Tadulako; and 3) extending the project (no-cost extension) from five to eight years due to funding support from The Nature Conservancy. The latter was invaluable as it enabled researchers to monitor rattan cultivation, management and effects associated with cane harvesting, and to investigate changes in the socioeconomic role and importance of rattan over a longer period of time and a wider geographic area. Collaboration with The Nature Conservancy also provided an immediate conservation outlet for research results.

Future Work

Project investigators will continue to analyze data and prepare manuscripts for publication based on the fieldwork for the next couple of years. Publications currently under preparation include:

Siebert, S.F. The sustainability of wild rattan (*Calamus zollingeri*) cane harvesting in Sulawesi, Indonesia.

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Ramadhanil Pitopang continues field research on the flora of Central Sulawesi and to expand University of Tadulako herbarium collections. P.I. Siebert will initiate comparative research on biodiversity and non-timber forest products in managed landscapes of Crete, Greece commencing in April 2002 with funding provided by a Fulbright Lecture/Research grant.

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