Oligarchic Forests of Economic Plants in Amazonia: Utilization and Conservation of an Important Tropical Resource

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Abstract: *Tropical forests dominated by only one or two tree species occupy tens of millions of hectares in Amazonia. In many cases, the dominant species produce fruits, seeds, or oils of economic importance. Oligarchic (Gr.* oligo = *few,* archic = *dominated or ruled by) forests of six economic species, i.e.,* Euterpe oleracea, Grias peruviana, Jessenia bataua, Mauritia flexuosa, Myrciaria dubia, *and* Orbignya phalerata, *were studied in Brazil and Peru. Natural populations of these species contain from 100 to 3,000 conspecific adult trees/ha and produce up to 11.1 metric tons of fruit/ha/yr. These plant populations are utilized, and occasionally managed, by rural inhabitants in the region. Periodic fruit harvests, if properly controlled, have only a minimal impact on forest structure and function, yet can generate substantial economic returns. Market-oriented extraction of the fruits produced by oligarchic forests appears to represent a promising alternative for reconciling the development and conservation of Amazonian forests.*

Resumen: *Bosques tropicales dominados por solo una o dos especies cubren millones de hectáres en la Amazonía. En muchos casos las especies dominantes producen frutos, semillas, o aceites de importancia económica. Bosques oligárquicos (del griego* oligo = *poco,* árquico = *dominado o gobernado por) de seis especies economicas,* Euterpe oleracea, Grias peruviana, Jessenia bataua, Mauritia flexuosa, Myrciaria dubia *y* Orbignya phalerata, *fueron estudiados en Brazil y Perú. Las poblaciones naturales de estas especies contienen desde 100 hasta 3,000 arboles adultos coespecíficos/ha y producen hasta 11.1 toneladas metricas de frutos/ha/año. Estas poblaciones de plantas son utilizadas, y ocasionalmente manejadas, por pobladores rurales de la región. Las cosechas periódicas de frutos, si estan controlladas, tienen un impacto ecológico mínimo sobre la estructura y dinámica del bosque pero pueden rendir ingressos economicos substanciales. La extracción comercial de frutos parece ser una alternativa promisoria para integrar el desarrollo y la conservación de los bosques Amazónicos.*

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Introduction

Tropical forests are usually characterized by a high diversity of tree species and low density of conspecific adults (Longman & Jenik 1974; UNESCO 1978; Whitmore 1984; Gentry 1988). In some habitats, however, where severe flooding, shallow soils, or frequent disturbance preclude the formation of species-rich forest, dense aggregations of a single tree species may occur. Forests dominated by only one or two tree species have been reported from almost every area of the wet tropics; notable examples include the *Shorea albida* Sym. forests of Sarawak (Anderson 1964; Brunig 1964), the *Mora excelsa* Benth. forests of Guiana and Trinidad (Davis & Richards 1933; Beard 1946), the *Gilbertiodendron dewevrei* (DeWild) Leonard forests of central Africa (Gérard 1960; Letouzey 1970; Hart et al. 1989), and mangrove (*Avicennia, Rhizophora*) forests throughout the world. Forests containing only a few palm species are especially common in tropical freshwater swamps (Moore 1973; Ruddle et al. 1978).

Oligarchic (Gr. *oligo* = few, *archic* = dominated or ruled by) forests are also known to occur in Amazonia (Ducke & Black 1953; Pires 1973; Pires & Prance 1985). These plant communities, however, have rarely been studied and little has been written about their ecological and economic importance in the region. This situation is somewhat surprising given that (1) oligarchic forests extend over several million hectares in Amazonia, (2) the dominant species in many of these forests produce fruits, nuts, oils, or other products of economic importance, and (3) these forest resources are exploited on a subsistence or commercial basis, or both, by many rural populations. Although the actual and potential value of oligarchic Amazonian forests is undoubtedly great, almost nothing is known about the density, yield, and management potential of these natural "monocultures."

The purpose of this report is to summarize the results of studies we have conducted on the ecology, use, and management of oligarchic Amazonian forests. High-density natural populations of six economic tree species are described, and population density, fruit yield, and market value data are reported for each species. Observations on the current use and management of these forest resources by rural people also are presented. Finally, the potential of oligarchic forest utilization as a viable land-use alternative in Amazonia is evaluated from both an ecological and an economic perspective.

Description of Study Species

Four palms and two dicotyledonous trees known to form dense natural populations in the uplands or seasonally flooded lowlands of Amazonia were examined in this study: *Euterpe oleracea* Mart. (Palmae), *Grias peruviana* Miers (Lecythidaceae), *Jessenia bataua* (Mart.) Burret (Palmae), *Mauritia flexuosa* L. (Palmae), *Myrciaria dubia* (HBK) McVaugh (Myrtaceae), and *Orbignya phalerata* Mart. (Palmae). Each of these species produces edible fruits or oils of commercial importance. The distribution, habitat, and principal uses of these six species are briefly described below. Habitat designations are based on extensive forest surveys and examination of herbarium specimens (AMAZ, INPA, MG, NY, USM); unreferenced use information is based on personal observation. Soil nomenclature follows the FAO-UNESCO (1971) classification system.

Euterpe oleracea ("açai") is a slender, multistemmed palm widely distributed in eastern Brazil (Cavalcante 1974). The palm is especially prevalent in the Amazon estuary, where it forms high-density populations along the banks of rivers, in lowland swamp forests on distric histosols, and, most importantly, in floodplain forests on eutric fluvisols (Fig. 1). Calzavara (1972) estimates that over 10,000 km^2 of the Amazon estuary are occupied by

Figure 1. Understory of Euterpe oleracea *forest on Ilha das Onças, Pará, Brazil, in the Amazon estuary. All of the small palms are regeneration of* E. oleracea. *(Photo by M. Balick.)*

oligarchic forests of *E. oleracea*. The species is an important source of palm heart in Brazil, and its fruit pulp provides a beverage that is a staple component of the regional diet (Balick 1984; Anderson 1988; Strudwick & Sobel 1988).

Grias peruviana ("sacha mangua") is a medium-sized tree native to the lowlands of northwest Amazonia (Prance & Mori 1979). The species is extremely abundant along the lower Ucayali river in Peru, where it forms dense groves in seasonally flooded forests. Oligarchic forests of this tree vary in size from 10 to 200 ha; soils are characteristically eutric fluvisols. The fruits of *G. peruviana* (Fig. 2) are eaten by rural people in many areas of Peruvian Amazonia, and a small local market for the species exists in Iquitos. An oil of unknown quality is also extracted from the fruit for subsistence use.

Jessenia bataua ("ungurahui," "pataua," or "seje") is a tall, single-stemmed palm (Fig. 3) common throughout Amazonia (Balick 1986). The species occurs as scattered individuals on well-drained upland soils, but forms extensive aggregations in seasonal swamp forests on gleyic podzols. Oligarchic forests of this palm are particularly well developed in western Amazonia; some of these forests extend over several hundred hectares (FAO 1986). The fruits of *J. bataua* are used to make a nutritious beverage, and a high-quality oil can be extracted from the mesocarp (Balick 1981, 1982). The physical and chemical composition of this oil is virtually identical to that of olive oil (Balick & Gershoff 1981).

Mauritia flexuosa ("aguaje" or "buriti") is a massive, dioecious palm that is widely distributed throughout lowland Amazonia. Oligarchic forests of this species occupy at least a million ha in Peru alone (Malleux-Orjeda 1975; ONERN 1976), and extensive populations have also been reported near the mouths of the Amazon and Orinoco rivers (Moore 1973). Along the Ucayali and Marañon rivers, dense aggregations of the palm (Fig. 4) are formed in permanently flooded backwater swamps along low upland terraces (Kahn 1988). The soils in these habitats are distric histosols. In terms of economic value and local popularity, *M. flexuosa* produces one of the most important market fruits in western Amazonia (Padoch 1988). The thin, oily mesocarp is eaten raw, or processed into a sweet paste for candies, beverages, and ice creams. The mesocarp and seed kernel also yield a good quality oil (Balick 1979).

Myrciaria dubia ("camu-camu") is a shrub or small tree native to western Amazonia (McVaugh 1963). It is a common component of the seasonally flooded riparian vegetation found along the banks of rivers and ox-bow lakes. The species is especially abundant in Peruvian Amazonia where it forms dense, monospecific stands along the watercourses associated with the Napo, Nanay, Ucayali, Marañon, and Tigre rivers. The fruits of *M. dubia* (Fig. 5) contain one of the highest concentrations of vitamin C (2,000–2,994 mg ascorbic acid/100 g of fruit pulp) in the plant kingdom (Ferreyra 1959; Roca 1965). There is a considerable local demand for the fruits, which are used to prepare juices, ice creams, and liqueurs.

Figure 3. Jessenia bataua *palms growing in seasonal swamp forest near the Rio Vaupés in the northwest Amazon of Colombia. (Photo by J. Zarucchi.)*

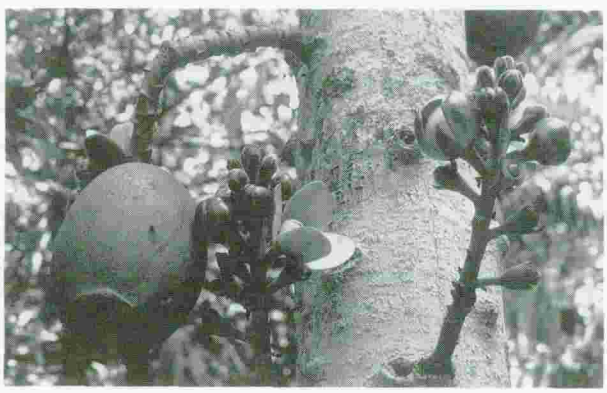

Figure 2. Flowers and fruit of Grias peruviana *in a seasonally flooded forest along the Rio Iricahua in Loreto, Peru. Fruit is approximately 15 cm long. (Photo by C. Peters.)*

Figure 4. Oligarchic forest of Mauritia flexuosa *on a low upland terrace of the Rio Ucayali in Loreto, Peru. (Photo by C. Peters.)*

Figure 5. Fruits of Myrciaria dubia *growing along the bank of Sahua cocha in Loreto, Peru. Large quantities of fruit are harvested from this stand every year and shipped to market in Iquitos. (Photo by C. Peters.)*

Orbignya phalerata ("babaçu") is a large, single-stemmed palm found along much of the southern and eastern fringe of Brazilian Amazonia. The species is tolerant of a wide range of edaphic and climatic conditions, and grows in both primary forest and secondary sites subject to intensive disturbance. It is especially common on abandoned agricultural land (Anderson 1983). Oligarchic forests of *O. phalerata* (Fig. 6) occupy almost 20 million ha in Brazil. Most of these forests occur on well-drained upland sites in the states of Maranhão, Piauí, and Goiás (May et al. 1985). The fruits of *O. phalerata* provide a variety of important subsistence and commercial products. The kernels contain an oil useful for cooking, soap-making, and burning; flour, animal feed, medicines, and beverages are produced from the mesocarp; the woody endocarp is also used to make charcoal (Anderson & Anderson 1983; Balick 1985).

Population Density and Fruit Yield

We conducted detailed inventories in Brazil and Peru to quantify the density and yield of oligarchic forests of these six species. Permanent study plots ranging in size from 0.1 to 1.0 ha were established in high-density populations of each species. The location and ecological characteristics of these plots are summarized in Table 1. Within each plot, all individuals of the dominant species ($\geq$1.0 m tall) were labeled and measured for height and diameter. The plots were visited periodically throughout the year to assess the phenology of flowering and fruiting and to identify the reproductive adults in each population. Fruits from a subsample of adult trees were then collected, counted, and weighed to estimate the average rate of fruit production. Production rates were multiplied by the total number of adult trees in each population to determine total population fruit yield. Detailed descriptions of the field procedures used with each species are contained in Anderson (1983), Anderson et al. (1985), Peters & Vazquez (1987), Kahn (1988), and Peters & Hammond (in press).

Local markets near the study sites were surveyed to determine the average price of the fruit produced by each species. Price data for *Euterpe oleracea* fruits were collected weekly in the Belém, Brazil, market during 1986. The produce market in Iquitos, Peru, was surveyed monthly in 1987 to determine the average price of *Grias peruviana, Jessenia bataua, Mauritia flexuosa,* and *Myrciaria dubia* fruits. Market prices for *Orbignya phalerata* were collected in the town of Bacabal, Brazil, during 1987.

The results from the field and market studies are shown in Table 2, which lists juvenile and adult tree density, annual fruit yield, and current market value estimates for a 1.0 ha population of each species. Three points in particular should be noted in this table. First, most of the species form natural populations that contain from 100–200 fruit-producing trees/ha. An extreme example is provided by the *M. dubia* population, which contains over 1,200 adults/ha. Second, all of the populations have more juveniles than adult trees. This is a key demographic characteristic because it suggests that seedling establishment is occurring at a rate sufficient to maintain each population at its present density. Third, and perhaps of greatest interest, natural populations of these six species produce from 1.2–11.1 t (metric) of fruit/ha/yr of considerable economic value. In terms of density and yield, the oligarchic forests examined in this study rival many commercial fruit orchards established in the tropics (Purseglove 1975; Williams 1975). The important difference, however, is that most of these wild populations occur on sites which are marginal from an agronomic standpoint.

Exploitation and Management of Oligarchic Forests

The rural inhabitants of Amazonia are well aware that many valuable fruit trees occur naturally in high density populations. Oligarchic forests play an important role in the subsistence and market economies of the region, and large quantities of fruit are harvested from them every year. Some of these tree populations are actively managed by local people to increase the yield of useful products.

The vast stands of *Euterpe oleracea* found along the floodplain of the Amazon estuary are exploited intensively for both fruits and palm hearts. Official government sources (IBGE 1983) report that almost 85,000 t of fruit and 99,000 t of palm hearts were extracted from these forests in 1982 alone. Most of this material was harvested in the state of Pará near the city of Belém. Although *E. oleracea* is a multistemmed palm that sprouts rapidly after cutting, uncontrolled palm heart extraction in the early 1960s severely degraded many oligarchic forests of this species and greatly reduced the total amount of fruit available for harvest. In response to this situation, floodplain farmers began to plant *E. oleracea* and to use pruning and weeding techniques to increase the density and yield of the palm in local forests (Anderson et al. 1985). Increasing market prices for the fruits have also helped to reduce the intensity of palm heart extraction somewhat in recent years.

Figure 6. Oligarchic forest of Orbignya phalerata *growing at Lago Verde in Maranhão, Brazil. (Photo by A. Anderson.)*

Most of the fruits collected from oligarchic forests of *G. peruviana* are consumed locally or sold in small quantities in rural villages. *Grias* fruits are frequently seen in the Iquitos market, but much of this material is collected from cultivated trees (usually *G. neuberthii* Macbride) growing in nearby swidden fields and home gardens. The oil contained in the fruit has little commerical value and is seldom extracted except for subsistence use.

Natural populations of *Jessenia bataua* were intensively exploited in Brazil during World War II, and in some years over 200 t of "pataua" oil were exported to the United States and Europe as a substitute for olive oil (Pereira-Pinto 1951). Assuming an average oil content of 8% (Balick 1988), over 2,500 t of *J. bataua* fruits were collected and processed to produce this quantity of oil. Unfortunately, the demand for "pataua" oil dropped considerably after World War II in response to the renewed availability of olive oil, and the palm is no longer used as a commercial oil source. *Jessenia* fruits, however, are still widely collected throughout Amazonia, and large quantities are sold locally every year to make beverages and ice creams and occasionally to extract oil for personal use. Uncontrolled felling of the palm to facilitate fruit collection has severely reduced the abundance of *J. bataua* around many market centers and rural settlements.

Mauritia flexuosa is undoubtedly the most intensely exploited and commercially important forest fruit in Western Amazonia. An official, yet decidedly conserva-

Table 1. Location and site characteristics of the six oligarchic forests examined in this study. Soils descriptions follow the FAO-UNESCO (1971) classification system.

Dominant species	*Location*	*Habitat*	*Sample area*
Euterpe oleracea	Ilha das Onças Pará, Brazil (1°25′S, 48°27′W)	Seasonally flooded forest on humic gleysols	1.0 ha
Grias peruviana	Iricahua River Loreto, Peru (4°55′S, 73°40′W)	Seasonally flooded forest on eutric fluvisols	0.6 ha
Jessenia bataua	Fiero Caño Loreto, Peru (4°55′S, 73°40′W)	Seasonal swamp forest on gleyic podzols	0.3 ha
Mauritia flexuosa	Iricahua River Loreto, Peru (4°55′S, 73°40′W)	Permanent swamp forest on distric histosols	1.0 ha
Myrciaria dubia	Sahua Cocha Loreto, Peru (4°55′S, 73°40′W)	Seasonally flooded riparian forest on eutric fluvisols	0.1 ha
Orbignya phalerata	Lago Verde Maranhão, Brazil (2°36′S, 44°25′W)	Disturbed upland forest on ferric luvisols	1.0 ha

tive, estimate from the Minesterio de Agriculture of Peru (1980) suggests that over 46 t of fruit were collected from oligarchic forests of this species in 1980. Padoch (1988), on the other hand, reports that the daily demand for *M. flexuosa* fruit in Iquitos averages 15 t, and that on some days production actually exceeds demand. Although a large percentage of this fruit is harvested from the extensive palm swamps found along the Marañon and Ucayali Rivers, collectors may travel three days to the Chambira River to harvest fruit during periods of extreme scarcity. The most serious problem facing the continued exploitation of *M. flexuosa* in Peru is destructive harvesting. Female trees are frequently cut down to collect the fruit, and with time the forest is left with a preponderance of barren male trees (Kahn 1988; Vazquez & Gentry 1989).

The commercial exploitation of *Myrciaria dubia* is relatively recent. In the late 1960s, a few merchants in Iquitos began to make juice drinks and sherbets out of the fruit on a trial basis. These products were well accepted by the public, and, within a few years, a small local market for the species developed. This market has continued to increase over the last 15 years. Most of the *M. dubia* fruits sold in Iquitos are collected along the tributaries and oxbow lakes of the Nanay, Napo, and Ucayali Rivers, and harvest levels in some of these sites are quite intensive. In 1985, for example, over 45 t of fruit were collected and shipped to Iquitos from a single oxbow lake (Sahua cocha; see Fig. 5) located near the town of Jenaro Herrera on the lower Ucayali River (Peters, unpublished data).

Table 2. Juvenile (≥1.0 m tall) and adult tree density, total annual fruit yield, and market value data for six oligarchic Amazonian forests. Yield data are expressed on a fresh weight basis; average production (mean ± SEM) shown when fruiting measured for more than one year or when replicate sample plots were used.

Species	*Juveniles (trees/ha)*	*Adults (trees/ha)*	*Fruit yield (t/ha/yr)*	*Market value (US$/ha/yr)*
Euterpe oleracea	775	267	1.2 ± 0.7	235
Grias peruviana	316	192	2.3	4,242
Jessenia bataua	944	104	3.5	306
Maritia flexuosa	415	138	6.1	1,525
Myrciaria dubia	7,490	1,224	11.1 ± 1.6	6,660
Orbignya phalerata	757	223	1.5 ± 0.1	23

The collection and sale of *Orbignya phalerata* fruits in northwestern Brazil is certainly the most dramatic example of the commercial importance of oligarchic forests. Over 250,000 t of *O. phalerata* kernels, or roughly 3 million t of fruit, were marketed in 1982 alone, these kernels providing over 80% of all the vegetable oil in Brazil obtained from nondomesticated sources (IBGE 1983). Almost 75% of these fruits were collected in the state of Maranhão, where the species ranks third, behind timber and rice, in terms of total revenue generated. The utilization of *O. phalerata* in Maranhão, however, is not limited to simple fruit extraction. Oligarchic forests of the species form an integral part of traditional agroforestry systems in which rice, corn, cassava, and a variety of other annual crops are planted under the palm (Anderson & Anderson 1983; May et al. 1985). Natural stands of *O. phalerata* are also selectively thinned by local people and seeded with pasture grasses to create grazing lands. Unfortunately, conflicts between landless shifting cultivators and ranchers in Maranhão are seriously threatening the continued viability of these management systems. Entire stands of the palm have been clear-cut and converted to pasture, farmers have been forced to reduce their fallow periods, and local fruit collectors have become increasingly dependent on *O. phalerata* trees left in planted pastures as a source of raw material (Anderson & May 1985; Anderson 1987; Hecht et al. 1988).

Potential for Increased Utilization

Oligarchic Amazonian forests are widely distributed, highly productive, and of great economic importance to the rural inhabitants of the region. From both an eco-

logical and an economic standpoint, increased utilization of these forests would be extremely beneficial.

In contrast to almost any other type of resource use practiced in tropical forests, fruit collection has little effect on forest structure and function. Canopy cover and floristic composition are maintained, the constituent fauna is preserved, and nutrient and hydrological cycles remain essentially unaltered. The collection and removal of large quantities of fruit is clearly a nutrient drain on the system, but given that most of these forests occur on sites subjected to seasonal flooding and sediment deposition, net losses are undoubtedly quite small. Intensive fruit collections also apparently have little impact on the dynamics of the tree populations being exploited. For example, using demographic data and projection matrix simulations, Peters (1989) has demonstrated that up to 90% of the seeds produced by natural populations of *G. peruviana* can be harvested without adversely affecting the long-term regeneration of the species. If harvests are properly timed and conducted in a nondestructive fashion, oligarchic forests can be exploited repeatedly, and quite intensively, with minimal ecological impact.

The economics of harvesting fruit from oligarchic forests are also extremely favorable. No initial investment is required, energy inputs such as fertilizer, herbicides, or pesticides are minimal, and cultural practices are rarely needed. There is also no waiting period between planting and first harvest as is the case with plantation management of fruit trees. The technology required to harvest and manage these forests on a sustained-yield basis is available to even the poorest rural populations. The only apparent costs involved are those associated with the collection and transport of fruits.

In spite of the variety of benefits afforded by this type of land use, increased utilization of oligarchic forests faces three fundamental problems. The first and most immediate is destructive harvesting. Although simple and effective methods for climbing trees are used every day in Amazonia — one good example is the rope sling, or "peconha," used in Brazil — these methods are apparently viewed as either too time-consuming or too labor-intensive by commercial fruit collectors. Clearly, oligarchic forest exploitation will never be sustainable as long as the dominant trees are felled to collect the fruits.

A second problem is that many oligarchic forests are located far from major market centers and processing facilities. This could imply high transport costs if conventional marketing systems are used, and, given the rapidity with which many fruits spoil, some forests may be too remote to exploit commercially. One potential solution to this problem would be to establish cottage industries near particularly large or productive forests with local residents being responsible for both the harvesting and the initial processing operations. In addition to reducing transport costs, this strategy would increase the share of product value accruing to local residents. It should be noted, however, that expanded markets and innovative processing technologies are sorely needed for many of these species.

A final, and especially complex, problem associated with the long-term utilization of oligarchic forests is the complex nature of the land tenure in many areas of Amazonia (Schmink 1982; Schmink & Wood 1987). As long as the property rights over a given tract of forest are not clearly defined, even the most sustainable forms of resource use are highly subject to disruption. The current situation of *Orbignya phalerata* in southeastern Brazil is a good example of this.

Conclusion

The concept of extractive reserves (Allegretti, 1989) has recently attracted a lot of attention as a promising method for integrating the utilization and conservation of Amazonian forests. Most discussions of this land-use alternative, however, have focused exclusively on species-rich forest, rubber (*Hevea* spp.) and Brazil nuts (*Bertholletia excelsa* H. et B.) being the important export commodities to be exploited. The results of our studies suggest that many of the high-density aggregations of useful plants found throughout Amazonia should also be recognized as suitable sites for implementing programs of controlled extractivism. These unique plant communities merit further study to obtain a better understanding of their ecology, management, and current and potential role in market and subsistence economies. Oligarchic forests are a conspicuous and valuable component of the Amazonian landscape. They offer an unprecedented opportunity to develop the commercial potential of several promising fruit species in a manner that is both economically viable and ecologically sustainable. It is surprising that the conservation and development of these important forest resources have been overlooked for so long.

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Literature Cited

Allegretti, M. H. 1989. Extractive reserves: an alternative for reconciling development and environmental conservation in Amazonia. In A. B. Anderson, editor. Alternatives to deforestation: steps toward sustainable use of the Amazon rainforest. Columbia University Press, New York (in press).

Anderson, A. B. 1983. The biology of *Orbignya martiana* (Palmae), a tropical dry forest dominant in Brazil. Ph.D. dissertation. University of Florida, Gainesville.

Anderson, A. B. 1987. Management of native palm forests: a comparison of case studies in Indonesia and Brazil. Pages 155–167 in H. L. Gholz, editor. Agroforestry: realities, possibilities and potentials. Martinus-Nijhoff, Dordrecht, Netherlands.

Anderson, A. B. 1988. Use and management of native forests dominated by açaí palm (*Euterpe oleracea* Mart.) in the Amazon estuary. Advances in Economic Botany **6**:144–154.

Anderson, A. B., and E. S. Anderson. 1983. People and the palm forest: biology and utilization of babassu forests in Maranhão, Brazil. Final report, Consortium for the Study of Man's Relationship with the Global Environment, USDA Forest Service, Washington, D.C.

Anderson, A. B., A. Gély, J. Strudwick, G. L. Sobel, and M. G. C. Pinto. 1985. Um sistema agroforestal na várzea do estuário amazônico (Ilha das Onças, Município de Barcarena, Estado do Pará). Acta Amazonica Suppl. **15**:195–224.

Anderson, A. B., and P. H. May. 1985. A palmeira de muitas vidas. Ciência Hoje **4**:58–64.

Anderson, J. A. R. 1964. The structure and development of the peat swamps of Sarawak and Brunei. Journal of Tropical Geography **18**:7–16.

Balick, M. J. 1979. Amazonian oil palms of promise: a survey. Economic Botany **33**:11–28.

Balick, M. J. 1981. *Jessenia bataua* and *Oenocarpus* species: native Amazonian palms as new sources of edible oil. Pages 141–155 in E. H. Pryde, L. H. Princen, and K. D. Mukherjee, editors. New sources of fats and oils. American Oil Chemists Society, Champaign, Illinois.

Balick, M. J. 1982. Palmas neotropicales: nuevas fuentes de aceites comestibles. Interciencia **7**:25–29.

Balick, M. J. 1984. Ethnobotany of palms in the Neotropics. Advances in Economic Botany **1**:9–23.

Balick, M. J. 1985. Current status of Amazonian oil palms. Pages 172–182 in D. V. Johnson, editor. Oil palms and other oilseeds of the Amazon. Reference Publications, Algonac, Michigan.

Balick, M. J. 1986. Systematics and economic botany of the *Oenocarpus-Jessenia* (Palmae) complex. Advances in Economic Botany **3**:1–140.

Balick, M. J. 1988. *Jessenia* and *Oenocarpus:* neotropical oil palms worthy of domestication. FAO Plant Production and Protection Paper No. 88, Rome, Italy.

Balick, M. J., and S. N. Gershoff. 1981. Nutritional evaluation of the *Jessenia bataua* palm: source of high-quality protein and oil from tropical America. Economic Botany **35**:261–271.

Beard, J. S. P. 1946. The Mora forests of Trinidad, British West Indies. Journal of Ecology **33**:173–192.

Brunig, E. F. 1964. A study of damage attributed to lightning in two areas of *Shorea albida* forest in Sarawak. Commonwealth Forestry Review **43**:134–144.

Calzavara, B. B. G. 1972. As possibilidades do açaizeiro no estuário amazônico. Boletim da Fundaçao de Ciências Agrárias do Pará **5**:1–103.

Cavalcante, P. B. 1974. Frutas comestíveis da Amazônia. Volume II. Publicaçoes Avulsas do Museu Goeldi, Belém, Pará.

Davis, T. A. W., and P. W. Richards. 1933. The vegetation of Moraballi Creek, British Guiana: an ecological study of a limited area of tropical rain forest. Journal of Ecology **21**:350–384.

Ducke, A., and G. A. Black. 1953. Phytogeographical notes on the Brazilian Amazon. Anais da Academia Brasileira de Ciências **25**:1–46.

FAO. 1986. Food and fruit-bearing forest species. Volume 3. Examples from Latin America. FAO Forestry Paper 44/3, Rome, Italy.

FAO-UNESCO. 1971. Soil map of the world. Volume IV. South America. United Nations Educational, Scientific and Cultural Organization, Paris, France.

Ferreyra, R. 1959. Camu-camu, nueva fuente nacional de vitamina C. Boletin de la Estacion Experimental Agricola La Molina **7**:28.

Gentry, A. H. 1988. Tree species richness of upper Amazonian forests. Proceedings of the U.S. National Academy of Sciences **85**:156–159.

Gérard, P. 1960. Etude écologique de la forêt dense à *Gilbertiodendron dewevrei* dans la région de l'Uele. Institut National Etude Agronomique pour le Congo (INEAC), Série Scientifique No. 87, Brussels, Belgium.

Hart, T. B., J. A. Hart, and P. G. Murphy. 1989. Monodominant and species-rich forests of the humid tropics: causes for their co-occurrence. American Naturalist **133**:613–633.

Hecht, S. B., A. B. Anderson, and P. May. 1988. The subsidy from nature: shifting cultivation, successional palm forests, and rural development. Human Organization **47**:25–35.

IBGE. 1983. *Produçao extrativa vegetal — 1982.* Volume 10. Fundaçao Instituto Brasileiro de Geografia e Estatística, Rio de Janeiro, Brazil.

Kahn, F. 1988. Ecology of economically important palms in Peruvian Amazonia. Advances in Economic Botany **6**:42–49.

Letouzey, R. 1970. Manuel de botanique forestiére: Afrique tropicale. Tome 2A. Centre Technique Forestier Tropical; Nogent-sur-Marne, France.

Longman, K. A., and J. Jenik. 1974. Tropical forest and its environment. Longman Group Limited, London, England.

Malleux-Orjedo, J. 1975. Memoria explicativa: mapa forestal de Perú. La Molina, Lima, Peru.

May, P. H., A. B. Anderson, M. J. Balick, and J. M. F. Frazao. 1985. Subsistence benefits from the babassu palm (*Orbignya martiana*). Economic Botany **39**:113–129.

McVaugh, R. 1963. Tropical American Myrtaceae. II. Field Museum of Natural History, Botanical Series **29**:315–532.

Ministerio de Agricultura. 1980. Anuario de Estadística Forestal y de Fauna Silvestre. Lima, Perú.

Moore, H. E. 1973. Palms in the tropical forest ecosystems of Africa and South America. Pages 63–88 in B. J. Meggers, E. S. Ayensu, and W. D. Duckworth, editors. Tropical forest ecosystems in Africa and South America: a comparative review. Smithsonian Institution Press, Washington, D.C.

ONERN. 1976. Inventario, Evaluación e Integración de los Recursos Naturales de la Zona Iquitos, Nauta, Requena y Colonia Angamos. Oficina Nacional de Evaluación de Recursos Naturales, Lima, Perú.

Padoch, C. 1988. Aguaje (*Mauritia flexuosa* L. f.) in the economy of Iquitos, Peru. Advances in Economic Botany **6**:214–224.

Pereira-Pinto, G. 1951. O oleo de pataua. Boletim Tecnico do Instituto Agronomico do Norte **23**:67–77.

Peters, C. M. 1989. Population ecology and management of forest fruit trees in Peruvian Amazonia. In A. B. Anderson, editor. Alternatives to deforestation in Amazonia: steps toward sustainable use of the Amazon rainforest. Columbia University Press, New York (in press).

Peters, C. M., and A. Vazquez. 1987. Estudios ecológicos de camu-camu (*Myrciaria dubia*) I. Producción de frutos en poblaciones naturales. Acta Amazonica **16/17**:161–173.

Peters, C. M., and E. J. Hammond. 1989. Fruits from the flooded forests of Peruvian Amazonia: yield estimates for natural populations of three promising species. Advances in Economic Botany (in press).

Pires, J. M. 1973. Tipos de vegetacao da Amazônia. Publicaçoes Avulsas do Museu Goeldi **20**:179–202.

Pires, J. T., and G. T. Prance. 1985. The vegetation types of the Brazilian Amazon. Pages 109–145 in G. T. Prance and T. E. Lovejoy, editors. Amazonia. Key Environment Series, Pergamon Press, Oxford, England.

Prance, G. T., and S. Mori. 1979. Lecythidaceae. Part I. The actinomorphic flowered New World Lecythidaceae. Flora Neotropica Monograph **21**:1–270.

Purseglove, J. W. 1975. Tropical crops: dicotyledons. Longman Group Limited, London, England.

Roca, N. A. 1965. Estudio químico-bromatológico de la *Myrciaria paraenis* Berg. Tesis de Ingeniero Agrónomo. Universidad Nacional de la Amazonía Peruana, Iquitos, Perú.

Ruddle, K., D. Johnson, P. K. Townsend, and J. D. Ress. 1978. Palm sago: a tropical starch from marginal lands. University of Hawaii Press, Honolulu

Schmink, M. 1982. Land conflicts in Amazonia. American Ethnologist: 341–357.

Schmink, M., and C. H. Wood. 1987. The "political ecology" of Amazonia. Pages 38–57 in P. D. Little, M. M. Horowitz, and A. E. Nyerges, editors. Lands at risk in the Third World: local level perspectives. Westview Press, Boulder, Colorado.

Strudwick, J., and G. L. Sobel. 1988. Uses of *Euterpe oleracea* Mart. in the Amazon Estuary, Brazil. Advances in Economic Botany **6**:225–253.

UNESCO. 1978. Tropical forest ecosystems. Imprimerie des Presses Universitaires de France, Vendôme, France.

Vazquez, R., and A. H. Gentry. 1989. Use and mis-use of forest-harvested fruits in the Iquitos area. Conservation Biology 3(4):350–361.

Whitmore, T. C. 1984. Tropical rain forests of the Far East. Clarendon Press, Oxford, England.

Williams, C. N. 1975. The agronomy of the major tropical crops. Oxford University Press, London, England.