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Babassu palm in the agroforestry systems in Brazil's Mid-North region

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Abstract. Babassu palms (*Orbignya* spp.) cover nearly 200,000 km² in Brazil, providing cash income, fuel, fibre, edible oil and food to a large number of tenant farm households. Babassu is closely integrated within pastoral and shifting cultivation systems of Mid-North Brazil. In pastures, babassu provides shade for cattle, aids soil moisture retention, produces organic matter, generates supplementary farm income at little cost, and offers year-round employment. On the other hand, the persistence of juvenile palms reduces pasture grass productivity due to plant competition, and therefore there is a trend to eradicate babassu through clearcutting and understorey suppression. At moderate densities of less than 100 individuals per ha, mature babassu palms in cropland do not appear to harm crop productivity. In such cases, palms are thinned and leaves of the remaining ones are cut back, supplying fuel for the burn and nutrients to the soil. However, reduced fallow cycles due to pasture conversion threaten babassu as well as crop productivity.

Resumo. Palmeiras de babaçu (*Orbignya* spp.) occorrem em quase 200.000 km² no Brasil, proporcionando renda em dinheiro, combustível, fibras, óleo e alimentos para cerca de quinhentas mil famílias de pequenos produtores rurais, a maioria arrendatários ou posseiros. O babaçu aparece integrado dentro de sistemas de produção pastorís e de agricultura migratória no Meio Norte do Brasil. Nas pastagens, o babaçu provê sombra para o gado, ajuda na retenção da umidade no solo, produz matéria orgânica, gera renda suplementar com investimento mínimo, e oferece condições para fixar a força de trabalho durante a entressafra dos produtos agrícolas. A presença de palmeiras juvenís, porém, reduz a produtividade dos pastos devido a competição, o que leva os criadores de gado a erradicar o babaçu, suprimindo tanto as palmeiras juvenís, como as palmeiras adultas.

No que diz respeito à agricultura migratória, o babaçu adulto em densidades moderadas, ou seja, até 100 indivíduos por hectare, aparentemente não reduz a produtividade das culturas anuais. Nestes casos, parte das palmeiras são desbastadas e as folhas das restantes cortadas, proporcionando combustível para a queima e nutrientes para o solo. No entanto, a redução nos ciclos de descanso devido à conversão das terras agrícolas em pastagens ameaça a produtividade quer do babaçu quer das próprias culturas.

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Introduction

The babassu palm (*Orbignya phalerata* Mart.*) and related species occur widely in Brazil, Bolivia, Colombia, Mexico and other parts of Latin America. Kernels extracted manually from babassu's thick-shelled fruit are a source of lauric oil having both edible and industrial uses. Figure 1 shows the distribution of babassu in Brazil. Over 80% of babassu kernel marketed in Brazil comes from the Northeast states of Maranhão and Piauí, known as the Mid-North region, which produces about 200,000 t of kernels annually (Table1). A major industry that expresses oil from these kernels is concentrated in the

Figure 1. Areas of occurrence of babassu palms in Brazil. States where babassu occurs are labelled. Heavy dotted line encloses the Mid-North region. Drawn by R. Alvares based on maps in [3] and [14].

*Also referred to in the scientific and popular literature as *Orbignya martiana, O. barbosiana, O.* spp. and other names.

Table 1. Area of babassu stands and their commercial exploitation in the Mid-North region of Brazil

Region	Area of stand occurrence		Kernels marketed (1980)	
	km^2	%	metric tons	%
Maranhão	103,040	53	183,455	73
Piauí	19,780	10	20,214	8
Mid-North (subtotal)	122,820	63	213,669	81
Other areas	73,550	37	37,282	19
Brazil	196,370	100	250,951	100

Sources: [11,14]

region. In 1980, over 30 oil factories operated in Maranhão alone [1]. Kernels constitute less than 8% of the fruit by weight although strains containing up to 17% kernel have been encountered. The remaining parts can be used industrially for production of charcoal, feedmeals and other by-products for which efforts have been initiated recently. These technological developments permit breaking babassu fruits mechanically and separation of their components for further processing.

Babassu kernels are third only to timber and rice in gross agricultural product value in Maranhão, where the economy relies on the primary sector for over 60% of its GDP. The palm also provides non-market goods and services to the rural population of the Mid-North region, in the form of fuel, fibre and food.

Babassu palms are seldom planted, but are managed within regional agroforestry systems, performing a vital role in the local economy.

1. General description of the area

1.1 Geographical location

The babassu zone of Mid-North Brazil includes portions of Maranhão north of 6°S., and east of 46°W., and of Piauí west of 42°W., bounded on the north by the Atlantic Ocean (Figure 2). Although most of the babassu zone is under 200 m in altitude, palms are found up to 1000 m. Babassu stands occupy over 120,000 km^2 in this region, some on upland sites and others in galleries along valley bottoms.

1.2 Historical evolution

The indigenous tribes which originally inhabited the region identified their territorial rights with stands of fruit-bearing palms such as babassu, which provided fuel and fibre as well as a reserve against famine [16]. After colonization by Europeans, the region became an important producer of sugarcane and later cotton on slave plantations. After slavery was abolished in 1888,

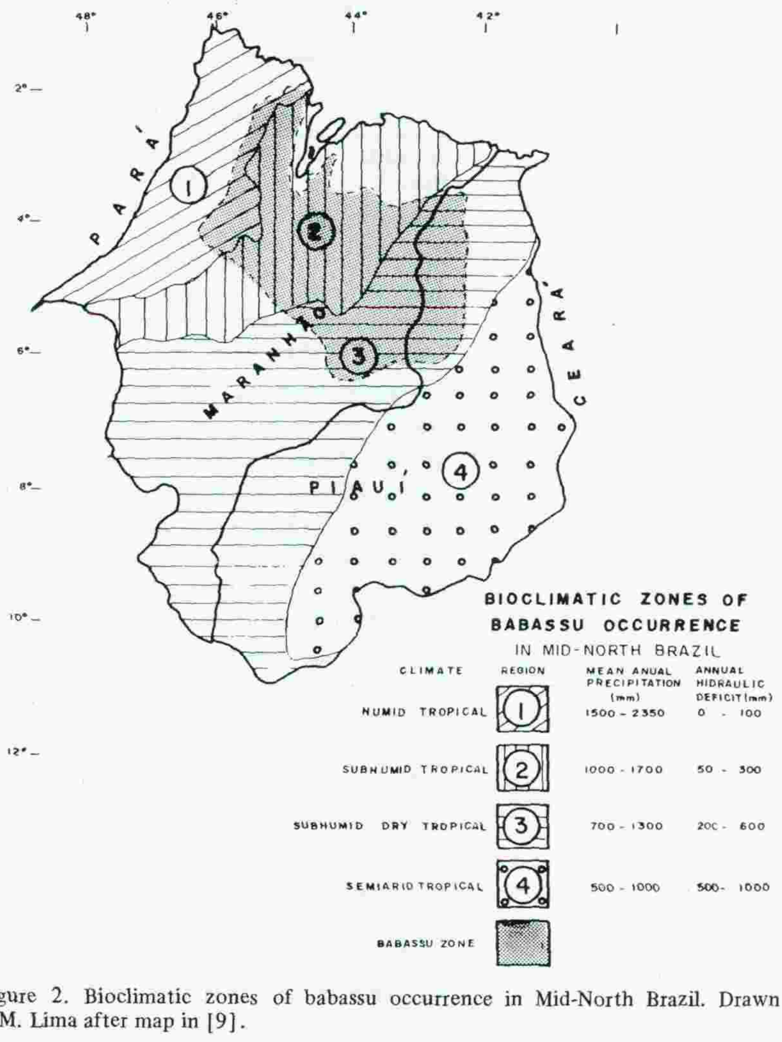

Figure 2. Bioclimatic zones of babassu occurrence in Mid-North Brazil. Drawn by R.M. Lima after map in [9].

the plantation economy collapsed; freed slaves and new immigrants established homesteads in unsettled areas where hunting, gathering and fishing complemented subsistence agriculture. The settlers relied on babassu palms for food, fuel and shelter. Since the 1920s, a steadily growing market for babassu kernels has contributed to inhabitants' cash incomes.

Most residents today are landless tenant farmers on properties controlled by a relatively small number of people (in Maranhão, 85% of the land is owned by 15% of the enterprises [10]). The landless pay in-kind for the right to live on the property and use the land for shifting cultivation, and must sell babassu kernels they extract to the landowner or his agent.

1.3 Biophysical environment

The Mid-North babassu zone is one of bioclimatic transition between Amazonian humid evergreen forests, savannas and woodlands (*Cerrado*), and semi-arid thorn scrub (*Caatinga*) of the Northeast. Annual mean temperatures range from 20–27°C. Seasonal rainfall varies within three pluviometric regimes (Figure 2) from 700–2100 mm annually [9], 90% of which falls unimodally from January to June.

Within the eastern dry '*Cerrado*' belt (700–1300 mm) babassu occurs in galleries along river banks whose alluvial sandy clays retain water during a 6–8 month dry season. Soils of the upland *Cerrado* are deeply-weathered sandy laterites. Babassu is sparse on these dry lands, whose vegetation consists mainly of leguminous trees and scrub with carnauba (*Copernicia prunifera*) palms appearing over unimproved range.

A more humid sub-region (1500–1800 mm) lies to the west, where alluvial deposits from three major rivers create well-structured alfisols with moderate P and N content, high cation exchange capacity and base saturation. Over 80% of land area is covered with babassu palms in this '*Cocais*' (palm forest) sub-region.

The 'Pre-Amazonic' zone (1600–2100 mm) lies on Maranhão's western frontier. Patches of tropical moist forest are interspersed with young secondary forest (*Capoeira*). Babassu is present in the former and dominant in the latter. As rapidly accelerating settlement encroaches on the Pre-Amazonic zone, dense babassu stands spread into the frontier.

1.4 Land use systems

1.4.1 Agriculture. In the *Cerrado*, mixed enterprise farms involve shifting cultivation within bottomland stands of babassu with beef cattle grazed on upland unenclosed range. In the *Cocais* and Pre-Amazonic regions, babassu and primary forests are being converted to improved pasture and some mechanized crop production. There are many dairy farms in the *Cocais*. Construction of paved highways in this region has strengthened rural-urban communications, yet most babassu zone farmland remains inaccessible to vehicles during the rainy season.

1.4.2 Forestry. Hardwood timbers from native forests are extracted to defray expenses of clearing new pasture and cropland at the frontier. National reforestation incentives have promoted landowners to plant eucalypts (*Eucalyptus urophila, E. braciana,* and *E. exta*) on poor *Cerrado* soils. Bamboo (*Bambusa vulgaris*) and pine (*Pinus caribaea*) are being planted in lowland areas cleared of babassu. Cashew (*Anacardium occidentale*) and coconut (*Cocos nucifera*) are also being established. Total area reforested between 1978–1983 is over 35 000 ha in Maranhão alone (Table 2).

The government has supported reforestation efforts using babassu in

Table 2. Area reforested per year by species: Maranhão

Year	(Hectares) Species Cashew	Coconut	Eucalypts	Pine	Bamboo	Total
1978	250	–	–	–	–	250
1979	1,100	250	–	–	–	1,350
1980	1,900	1,400	200	–	–	3,500
1981	1,710	930	2,800	1,600	1,500	8,540
1982	3,088	870	5,920	2,400	1,500	13,778
1983[a]	3,270	850	3,250	700	900	8,970
Totals	11,318	4,300	12,170	4,700	3,900	36,388

[a] Figures for 1983 are based on areas proposed for reforestation under IBDF programmes, and not area actually reforested.
Source: Personal communication: Instituto Brasileiro de Desenvolvimento Florestal (IBDF), Delegacia Estadual do Maranhão

several states with strongest impetus during a period in the late 1970s when babassu fruit mesocarp first began to be considered as a potential source of fuel ethanol. None of the attempts to establish babassu plantations have been of notable success. One reason for this is the lack of knowledge of appropriate agronomic techniques for nursery and field planting or management. Recent studies have found that babassu, like most palms, flourish best if first planted under nursery conditions, in polythene bags which allow for the deep root growth characteristic to the species.

Trees are seldom planted for fuel or fencing. Secondary forest fallows provide for most polewood, and babassu husks furnish the major source of cooking fuel in rural areas. The majority of rural households use babassu charcoal as their principal fuel (Table 3).

1.4.3 Agroforestry-type systems/practices. There are two general agroforestry practices involving babassu: (1) palm-pasture; and (2) palm-shifting cultivation. These systems are associated and together cover much of the region. The first involves pastures planted under native palm stands thinned of senescent and unproductive palms; babassu shades cattle, and it protects and replenishes soils. The second involves shifting cultivation within native babassu stands, where babassu leaves provide fuel for the burn, and mature palms are retained over crops to provide a range of subsistence and market products during the fallow cycle [3, 12]

2. Structure of the system

2.1 Components of Babassu agroforestry systems

2.1.1 Crops. Shifting cultivation typically consists of intercropped rice (*Oryza sativa*), maize (*Zea mays*), cassava (*Manihot esculenta*) and several

Table 3. Proportion of rural families using babassu products in Maranhão municípios. n = Sample size

Municipio	Thatch	Basketry	Charcoal	Milk	Oil	Palmito
	Percent of families interviewed					
Bacabal[a] (n = 104)	86	96	96	44	53	n.a.
Lima Campos[b] (n = 64)	94	83	92	70	66	8
São Bento[b] (n = 57)	76	72	49	72	74	16
Chapadinha[b] (n = 98)	86	90	96	89	91	42
Average	86	85	83	69	71	22

[a] Source: [3]
[b] Source: P. May (unpublished data)

bean species under babassu palms. Rice is by far the region's most important crop and is used as a payment for land rental, a cash crop, and a principal source of sustenance. Over 125 regional upland varieties are in use [7]. Maranhão is one of the major rice producing states of Brazil, even with traditional methods. Dried maize is used as feed for animals and rarely sold. Bitter cassava is used for making flour ('dry' or fermented '*farinha d'agua*'), which is a basic staple. Cowpeas (*Vigna sinensis*) and lima beans (*Phaseolus lunatus*) are also primarily for subsistence consumption. Among other cultivars planted are squashes (*Cucurbita* spp.); watermelon (*Citrulus lanatus*); West Indian gherkin (*Cucumis anguria*), locally known as '*machiche*'; okra (*Hibiscus esculentus*); cucumber (*Cucumis sativa*); and banana (*Musa* spp.).

2.1.2 Trees and other woody perennials. Dominant species found in babassu-associated secondary forests and their principal uses are listed in Table 4. Regrowth cycles of secondary forest correspond with long fallow periods of shifting cultivation, after which useful tree species are harvested as polewood or timber during land preparation for cultivation. Other palms, such as carnauba, buriti (*Mauritia flexuosa*) and tucum (*Astrocaryum vulgare*) occur in varying abundance in association with babassu, and furnish oils, food, waxes, fibre, and construction materials to rural households.

By far the dominant woody species encountered in these systems is the babassu palm (66% dominance in 1 ha of secondary forest in the *Cocais* [2]). Babassu dominates the landscape due to its cryptogeal mode of germination, in which the growing point (*apical meristem*) initially grows underground, remaining until the stem emerges several years later. This adaptation permits juvenile palms to survive the cutting and burning associated with shifting cultivation.

According to local farmers interviewed, babassu palms attain fruiting stage

Table 4. Uses of principal woody species found in babassu agroforestry systems

Species	Local name	Uses
Spondias mombim	*Cajá*	edible fruit
Inga spp.	*Ingã*	edible fruit
Cecropia spp.	*Imbauba*	leaves eaten by sloths (game meat)
Acacia spp.	*Unha de gado*	construction, fence posts
Tabebuia spp.	*Pau d'arco*	construction, fence posts
Cedrella odorata	*Cedro*	construction, fence posts
Astrocaryum vulgare	*Tucum*	oil, basketry
Mauritia flexousa	*Buriti*	edible fruit, thatch, basketry
Copernicia prunifera	*Carnauba*	wax, basketry, contruction
Acrocomia sclerocarpa	*Macauba*	oil, meal
Euterpe oleacea	*Juçara*	palmito, edible fruit
Orbignya phalerata and *O. teixeirana*	*Babaçu*	oil, charcoal, thatch, feed, basketry, construction
O. eichleri	*Piaçava*	basketry, brushes

after 10 to 12 years under optimal condition (although there are no controlled trials to confirm this). Adult palms produce a single inflorescence with each new leaf. Panicles contain ca. 200 fruits averaging 190 g each (range: 80–450 g). Fruits are mostly collected from the ground and broken manually by women and children by hitting with a club and breaking the fruit against the upright blade of an axe. Most kernels extracted in this way are sold and the husks used to produce charcoal. The importance of babassu products for the subsistence economy of the region has recently been measured [3, 12] (Table 3).

2.1.3 Animals. Landowners typically have more numerous and varied livestock than their tenants. Prosperous families raise guinea hens, turkeys, ducks and geese, along with pigs, goats and sheep (all consumed by the family and slaughtered during local festivals). Most families have a few chickens; some have mules, donkeys, horses and oxen as beasts of burden. There is very little use of animal traction for cultivation. Small farmers rarely own cattle; those that have a few head frequently rent pasturage rights from landowners at monthly rates which averaged the equivalent of US\$ 2.75 head^{-1} in early 1983 [8]. Animals are fed babassu leaves from juvenile palms, kernel residues, palm heart and mesocarp meal, as well as cassava peelings, corn and crop residue.

Ranchers raise herds of cattle and some water buffalo. Ranchers have been investing gradually in improving their local '*pé duro*' mixed cattle breeds. The preferred cattle species are '*Zebu*' and '*Nelore*' breeds of Brahman stock, and '*Holandês*' dairy cows. Cattle are generally range-fed on native and planted pastures and on young secondary forest regrowth in fallowed cropland. There is little use of silage or stored grains as feed.

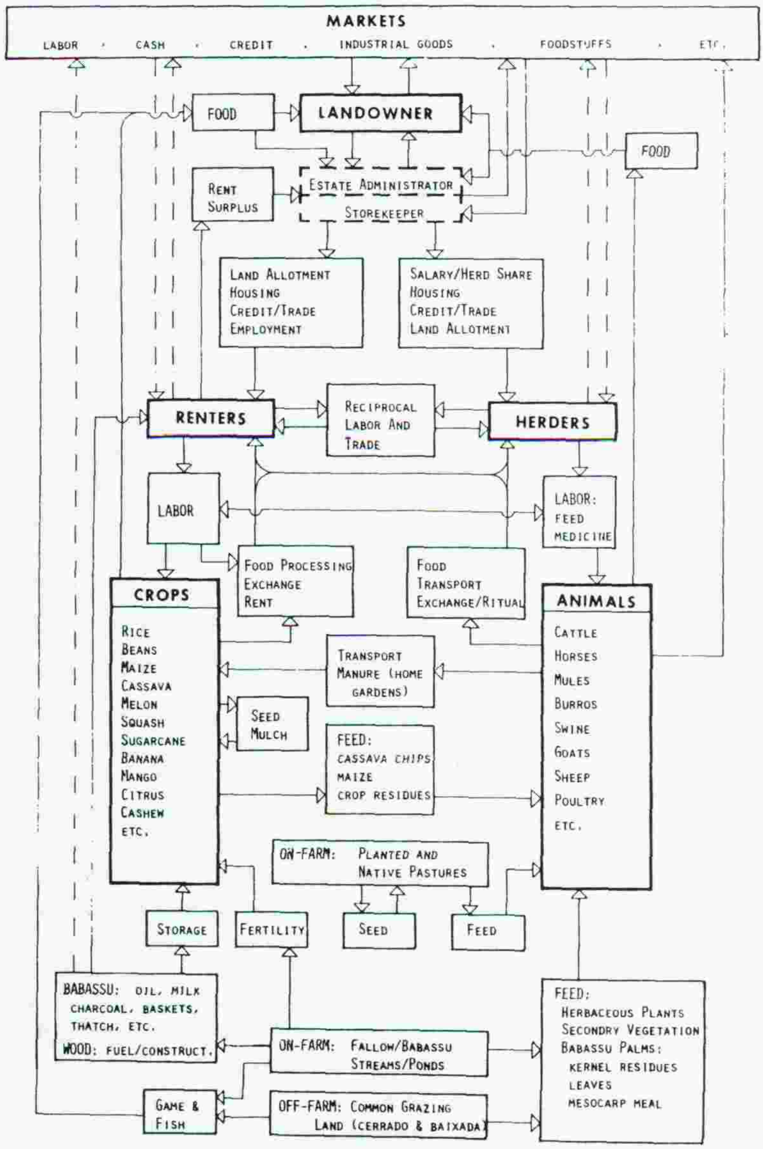

Figure 3. Principal interactions in traditional babassu agroforestry systems in Mid-North Brazil. Drawn by J. Barki based on a diagram by P. May.

Pastures are managed at low stocking rates, seldom exceeding one animal unit per ha. More modernized operations involve pasture rotations. The most popular pasture grasses are *jaraguá* (*Hyparrhenia rufa*), *colonião* (*Panicum maximum*), and one or more species of *Brachiaria*. Fodder grasses, particularly elephant grass (*Pennisetum purpureum*), are also planted in small areas, cut into forage and fed to cattle during the dry season, along with cassava chips and babassu oil press cake.

2.1.4 Game and fish. Small farmers rely to considerable extent on hunting and fishing for animal protein. Several large rodent species such as *cotia* (*Dasyprocta punctata*) and *paca* (*Agouti paca*) abound in the palm forests, feeding on the mesocarp of fallen babassu fruit [14]. Game potential in babassu forests is enhanced by this feed source. Rodents' removal of the mesocarp also appears to stimulate germination in babassu [2] thus making the relationship somewhat symbiotic. Fishing is done in even the smallest freshwater streams. Game animals and fish are cooked in babassu-kernel milk and home-made oil.

2.1.5 Synthesis of traditional systems. Figure 3 schematically describes the composite structure of traditional babassu agroforestry systems following a format developed for descriptions of similarly integrated crop and animal production systems throughout the tropics [13]. This diagram, which is self-explanatory, shows interconnections between different enterprises of landowners and tenants, as well as the social relations of production through which these enterprises function.

2.2 Arrangements/interaction of components

In babassu-associated cropping systems, stands are thinned of senescent and unproductive palms to between 50 and 100 adult palms ha^{-1}. The leaf biomass in babassu stands is exceptionally high. On a 1 ha site in the *Cocais* region the leaf biomass totalled 52.7 t dry weight (DW) and an annual leaf production of 16.8 t DW was recorded [2]. A burned stand requires about 4 years to recover its full biomass of leaves. After the annual burn in October, emergent (but still immature) panicles exposed to fire are worthless for kernel extraction, as the liquid endosperm is destroyed by excessive heat. However, productive palms quickly regain productivity and recover completely after approximately 2–3 years, according to local farmers. This occurs because non-emergent inflorescences are protected from fire by heavy leaf sheaths. Cutting of leaves, which is also a common practice to meet the farmers' storage and shelter needs, also serves to increase light penetration during the subsequent growing season.

Harvesting of babassu fruit from fallow sites is a regular aspect of regional farming activities. Fruits commence to mature and drop from the panicle in August, continuing through the beginning of the rainy season in January, when planting of annual crops commences. People continue gathering babassu fruit from the ground during the rest of the crop cycle as a secondary activity, limited by labour requirements in weeding and harvesting annual crops, as well as reduced accessibility of stands due to flooding.

In the crop field, farmers plant rice densely in holes about 20 cm apart

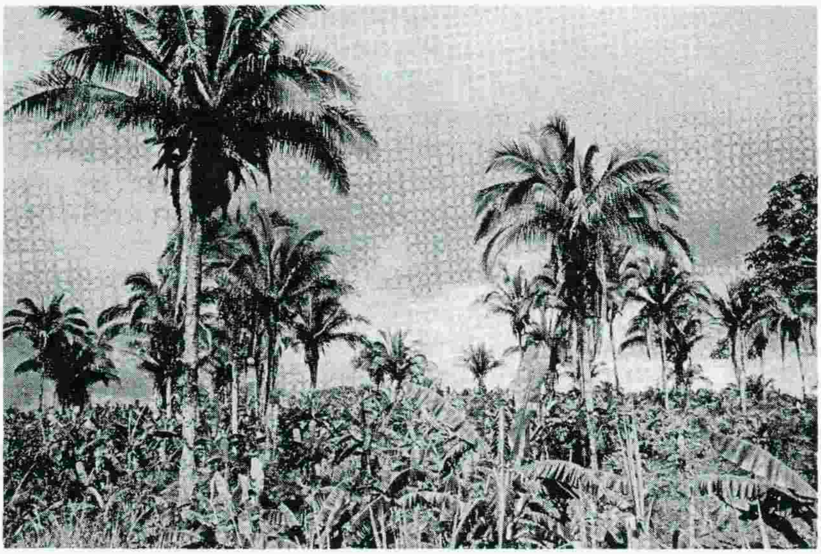

Figure 4. Bananas growing under babassu palms in Lima Campos, Maranhão. Photograph by P. May

and maize in hills in rows up to 2 m apart among the rice. Cassava is also planted sometimes between these maize rows. Beans are either planted around maize stalks and babassu trunks, drilled in rows in a separate destumped plot, or scattered in a previously cropped site. Earlier in the season, farmers randomly plant the other crops (e.g., watermelon, okra, squash, etc.) within the annual crop field.

Harvesting of annual crops begins in late March after two manual weedings. Farmers first harvest early rice varieties, green corn and beans for household consumption. Most of the harvest period is devoted to rice cutting, after completion of an average 120-day cycle. Farmers store rice on the sheaf in shelters covered with babassu leaves. After breaking stalks during the rice harvest, maize dries in the field until August to October, when it is harvested and stored as grain. Farmers usually plant additional cassava at the end of the rice harvest, which extends the life of the crop field. Cassava varieties in use typically require up to 18 months to mature, after which household members harvest the tubers as needed for flour production, which peaks in the slack period before new land clearing. Once they harvest the cassava, they abandon the plot to secondary forest fallow dominated by babassu. Banana planted under babassu also extends the life of the cropping system (Figure 4).

In most planted pastures, palms are retained at 50–120 stems ha^{-1}. Ranchers also tend to thin unproductive palms. This appears to promote the growth of pasture grasses and increase palm yields. Total fruit productivity of palms per unit area inventoried within 136 blocks in a uniform-aged stand on a yellow latosol in the *Cocais* increased linearly with stand density to about 120 stems ha^{-1}, beyond which growth in yield tended to drop-off with increased stand density (Frazão and May, unpublished data). Palm stands with pastures underneath as compared with secondary forest facilitate safer collection of fruits because of reduced undergrowth and the ease of sighting snakes. Ranchers interviewed asserted that pastures under palms retained moisture better and had higher productivity in comparison to open conditions. On the other hand, juvenile palms must be frequently cut back to avert competition with pasture grasses, representing a major cost to the rancher (averaging the equivalent of US\$ 15 ha^{-1} yr^{-1} for manual cutting). For this reason, some ranchers consider babassu a serious weed problem that they attempt to permanently eradicate with herbicides or soil grading. Suppression of juvenile palms, however, will result in stand degradation of babassu after about 50 years, due to senescence of the remaining palms.

System functioning

3.1 Resource input and utilization

3.1.1 Land. According to the 1980 census [10], fallows and forest account for 66.5% of agricultural lands in the *Cerrado*. In the *Cocais*, pastures dominate (47.9%), with proportionally smaller areas in fallow and forest. The landowner allocates land annually to tenants for shifting cultivation at his discretion. Unwritten tenancy contracts involve a fixed rent which represents up to 30% of average rice yields in traditional intercropping systems for each land unit cultivated by the tenant farmer. Annual shifting cultivation plot areas averaged 1.0 ha in the *Cerrado* and 2.3 ha in the *Cocais* in the period 1982–84; this may be lower than normal due to drought (May, unpublished data). Area under crops per household is more for landowners than for tenants, but usually involves similarly rudimentary technology.

3.1.2 Labour. Households average 4 persons, yet express a considerable range in size, and are not stable in composition. This is because active males migrate to mining and urban areas either seasonally or year-round, so there are usually more women, children and older people in permanent residence within landless households. Land preparation (clearing, burning, fencing) is done by adult males. Given labour shortages, the household may employ daily workers (50% of families surveyed used this tactic), or engage in labour exchanges (*'troca de dias'*) with other households to reduce labour costs and assure timely completion of essential tasks. Daily wages averaged US\$ 1.50 in 1983–84. Women and children are occupied in babassu fruit collection and breaking during the entire land preparation period (August–December). Agricultural operations in February and March (weeding) and May–June (harvesting) may require more family members to be involved in those so that the quantity of babassu fruit harvested declines during this period.

This pattern of labour allocation ensures the availability of a steady labour

Table 5. Per capita weekly income by source: average of 75 households in 3 Maranhão municípios, Oct.–Dec. 1983

Source	Cash Cr$[a]	%	Non-cash Cr$	%	Total Cr$	%
Babassu	597	39.7	217	26.0	814	34.8
Non-Babassu	906	60.3	617	74.0	1,523	65.2
Totals	1,503	64.3	834	35.7	2,337	100.0

[a] Exchange rates averaged Cr$ 1000 per US$ during this period.
Source: [12]

force throughout the year. Landowners employ their tenants and, at peaks, hire non-resident labourers, whose wages will be paid in cash or kind (usually a fixed amount of the crop harvested, but also in meat; labourers customarily receive a meal as part of their wage). Although no labour obligations to the landowner are built into the tenancy contracts, the estate residents are generally regarded as a reserve labour force that can be called upon when needed. Tenants are also employed in herding landowners' livestock, for which they receive a share of the calves, typically one in every four calved.

3.1.3 Capital. Small farmers accomplish most tasks with help of little more than an axe, a hoe, a sickle, and a machete. Sales of babassu kernel finance the household's cash requirements up to the next harvest (Table 5). Landowners use the cash flow from babassu products resale and other revenues most frequently to invest in the expansion of cattle herd or pasture rather than in mechanization. Nevertheless, there has been considerable growth over recent years in tractor utilization for pasture establishment and management, as well as some mechanization of rice production. These projects have largely been financed by banks and Federal Government subsidies rather than capitalized from revenues of current production.

3.1.4 Inputs. Chemical fertilizers are rarely used in crop production, though most producers use manures and decomposed babassu stems as a planting medium for kitchen gardens. Pesticides are in more frequent though sparing use. Many rely on spells and prayer to ward-off crop failure, though these are of little help in combatting the drought cycles which have begun to affect the region from the neighbouring semi-arid zone. Most seed is retained from the previous harvest by farmers who prefer to perform their own seed selection rather than rely on goverment sources. Large landowners have easier access to bank credit than do their tenants, using either land or anticipated production as collateral. The national bank has special credit schemes at low interest rates to help cover small farmers' production costs. Nevertheless, most farmers complain of problems in securing or obtaining timely release of production loans.

Table 6. Production and value of principal crops and babassu per unit area

Crop	Average output/ha	Gross value/ha (US$)[a]
Rice (unhulled)	1.36 t	$150.40
Maize (grain)	0.47 t	45.37
Beans	0.31 t	184.63
Cassava (roots)	6.40 t	128.83
Banana	1,102 bunches	517.94
Babassu Kernel	0.14 t	74.31
Babassu Charcoal	0.45 t	26.87

[a] In April–June 1984 average market prices. Net revenues would be somewhat lower.
Sources: [4, 10, 13] and PH May (unpublished data).

3.2 Production

Outputs vary widely among farmers, agro-ecological regions, and over time; average figures are given in Table 6. They may be slightly biased by output from non-intercropped or mechanized production, which represents a small proportion of overall crop output. Cassava and bananas are successional species in annual crop fields. Babassu output is for normal fallow cycle production of 2 t ha^{-1} in average regional stands (fruit yields range from less than 1 to over 6 t ha^{-1}).

Pé duro cattle breeds raised on the *Cerrado* seldom achieve marketable beef weight over 100 kg in 3–5 years at extremely low stocking rates; this output is somewhat lower than the Brazilian average of about 125 kg, most raised on comparably extensive range. Superior breeds raised on improved pastures in the *Cocais* yield considerably more meat in a shorter period at higher stocking rates, which helps to explain why much of this region is giving way to pasture.

The Mid-North region rarely experiences drought. Abnormally dry rainy seasons between 1980 and 1983 resulted in significant cropland and herd adjustment. Small farmers were unable to save sufficient quantities of seed for planting; to avert risk they planted considerably less area than normal. Sale of babassu kernel and off-farm income were crucial to maintain household income.

3.3. Protective and service aspects

Besides a number of important subsistence products such as thatch and basketry, babassu leaves contribute to the sustainability of shifting cultivation systems. Given a long enough fallow period, babassu leaf biomass provides sufficient fuel and nutrients so that mature palms may be retained when clearing secondary forests for crop production. High leaf productivity enables shifting cultivators to return to the same site within four or five years. In addition, microclimate conditions under palms may promote moisture retention in soils. On hillsides, palms appear to prevent soil erosion, both through crown protection against exposure to erosivity caused by direct rainfall and root binding of soils. Utilization of babassu fruit husks for charcoal reduces deforestation pressure on other woody species that would otherwise be used as fuel sources.

3.4. Socio-economic description

Small farmers incur mounting indebtedness during the period between harvests. Capital peaks at the termination of the rice production cycle in July. Cash flow derived from babassu kernel sale is fairly constant from September through January, providing an important supplement to stored grain. When goods stored from the harvest and babassu income become insufficient, goods are purchased on credit from landowners and local shopkeepers. This debt is sometimes not fully defrayed at harvest time. This creates strong dependency relationships which go beyond purely economic ties to the landowner or other source of credit. Formal organization among small tenant farmers is minimal, probably due to their fragmentation and dependency on their landlords. Rural workers' unions have been formed, attempting to assure job security for wage workers and to mediate land title disputes between smallholders and speculators. Such disputes are particularly severe in the Pre-Amazonic region, where squatters are losing battles to secure legal title.

4. System dynamics

4.1 Rate of growth – expansion/degradation

The historical growth in babassu kernel production is directly related to population increase and frontier expansion in the region. Migration from drought-stricken and mechanizing areas of Northeast Brazil swelled Maranhão's population by 430,000 between 1950–1970. Land use change and rural employment shifts have affected areas of the babassu zone at different times. During the 1960s, the *Cocais* was the area of most rapid population growth; during the 1970s, the highest growth rates were observed in the Pre-Amazonic region. Conversion to pasture in the *Cocais* forced many small farmers to migrate to the west where there were then relatively more free lands. Accompanying this migration has been a gradual expansion of babassu stands into the Pre-Amazonic region, as primary forests are cleared for shifting cultivation.

The amount of land available for shifting cultivation has been reduced by widespread conversion to pasture, resulting in a decline in productivity of crops as well as of babassu palms, in areas remaining available for cultivation. With degradation of shifting cultivation sites, the rural poor are becoming increasingly dependent on pasture stands of babassu as a source of income and subsistence products. Despite its beneficial attributes, ranchers often treat babassu as marginal to their overall enterprises. People who gather babassu fruits are perceived as interfering with pasture management, being blamed for starting wildfires, cutting fences, and leaving behind fragments of fruit husks that can cause injury to the hooves of cattle. To rid themselves of such incursions, ranchers are increasingly clearcutting the palm forests.

Ranchers who receive government subsidies for pasture establishment are encouraged to remove native forest, which in practice represents a further incentive to clear babassu. From 1967–1980, 72 such projects were approved for financing in Maranhão alone, on an area totalling over 1 million ha [1]. Babassu stands are also being felled to make way for mechanized rice operations, as well as plantations of sugarcane and bamboo.

These projects correspond with national efforts to stimulate agricultural exports to service international debt or substitute for imported fuels. Babassu, an indigenous plant resource of considerable local economic significance, is being substituted by export crops from the region. Though state laws prohibit clearcutting of babassu in an attempt to preserve moderate densities of palms in pasture systems, these laws are unenforceable. We suspect that the rate of deforestation is increasing exponentially in more humid and fertile areas, due to the combined pressures of pasture conversion, breakdown of shifting cultivation, and establishment of permanent agricultural systems.

4.2 System sustainability

The future role of babassu in regional farming systems largely depends on the attitudes of the people who own and manage the land. In regions where land uses are intensifying such as the *Cocais* and Parnaiba Valley, the palm is often considered marginal due to its low yields and slow growth. In these relatively fertile areas, babassu's continued dominance of the landscape appears to be seriously threatened. Yet the palm has shown a remarkable capacity to recover and eventually dominate landscapes where intensive forms of land use were practised in the past.

In drier, less fertile areas, such as the *Cerrado* region in Maranhão and most of the babassu zone of Piauí, the palm is still an integral part of traditional land use systems and will probably remain so.

5. Evaluation

5.1 Merits

The productive and service functions of babassu in traditional systems are ranked as follows:

1. Babassu is an important source of vegetable oil and feed cake and has considerable unrealized potential to supply fuels as well as other industrial products such as starch and tar.

2. Cash income from sale of babassu products (principally kernels and charcoal), constitutes a significant share of small farmers' income obtained during the period between harvests of annual crops. This income, which is

generated principally by women and children whose labour is not critical to agricultural activities in the land preparation phase, strongly complements that derived from other activities and provides a risk cushion in the event of crop failure.

3. A wide variety of subsistence products, consisting chiefly of charcoal, thatch, basketry, edible oil and food products, feed and fodder is obtained from the palm by small farm families.

4. High biomass production provides farmers with sufficient material for fuel in shifting cultivation systems, without requiring drastic thinning of the stands.

5. Land coverage by babassu palms appears to promote soil moisture retention and improve pasture productivity, as well as providing shade for cattle.

5.2 Weaknesses/constraints

1. Low current fruit productivity in wild stands of babassu leads to their replacement with open pastures, mechanized crop production and even other trees.

2. Pasture encroachment diminishes land available for shifting cultivation, and reduces the duration of fallow cycles, which compel shifting cultivators to drastically thin or clearcut the very palm stands on which they depend for a sizeable share of their incomes.

3. Ranchers consider juvenile palms noxious weeds that compete with pasture grasses due to their capacity to survive cutting and burning.

4. Stands maintained over pastures are subject to gradual deterioration as new growth is suppressed.

5. Utilization of existing stands for kernels accounts for only about 30% of total fruit production, due to low value of product, inaccessibility, and prohibition against collection.

6. Efforts to develop technology for processing whole babassu fruit and marketing them threaten to reduce employment and subsistence benefits from the existing cottage industry.

7. Inequitable land distribution constrains the prospects for developing babassu-based agroforestry systems.

5.3 Potentials

1. Babassu's attributes as providor of a wide range of products, its ease of establishment and maintenance, and its current close integration with extensive production systems on marginal lands could be enhanced by a breeding programme to upgrade productivity of apparent natural hybrids of babassu with palms such as *inajá* (*Maximiliana maripa*) and *piassava* (*Orbignya eichleri*) to select strains more tolerant of dry and nutrient-poor soils.

2. Babassu palms could be retained on hillsides in fertile regions as a means of preventing soil erosion; increased market demand for whole babassu

fruits will make this attractive to landowners.

3. There is a potential for stand and yield improvement through dissemination of secd from prolific stands encountered in the wild, or genetically improved strains. For example, there are reports of babassu fruits containing up to 17% kernel, in contrast with the average of 7%; exploitation of such strains for oil would prove advantageous. Corresponding variations have been noted in fruit size, endocarp weight, and hardness, all of which affect industrial viability. From the farm production perspective, recent fieldwork in Pirapora, Minas Gerais has identified babassu palms demonstrating yields 500% higher than average yields in the Mid-North region (M Balick, J Frazão, J Costa, J Veira, unpublished data). Occurring in a palm-pasture combination, this population of a distinct species (*Orbignya oleifera*) was estimated to produce ca. 10 000 kg fruit ha^{-1} yr^{-1}.

4. Available technology for mechanical processing of whole babassu fruits can be scaled-down to the level of the producer; fruit components can be more completely utilized within the farm system, for feed, fuel and fibre, with kernels and charcoal still being supplied to regional industries. With such a technology, part of the estimated 70% of fruit output that is currently under-utilized could become economically harvestable.

5.4 Extrapolability

Babassu-related agroforestry practises with present productivity levels show greatest promise in areas having marginal soils and sparse population, where the palm's multiple products can contribute to diversified shifting cultivation and pastoral farming systems. With crop improvement efforts already underway, the palms also are promising as fuel, food and fibre generating components of more intensive production systems in a wide range of tropical environments.

5.5 Research needs

1. Highest in priority should be a focus on the potential of apparent natural hybrids of babassu with *inajá* and *piassava* for reforestation of marginal areas. This would involve selection of seed from promising native stands or individuals, development of seed propagation techniques, and testing of growth performance on representative soils.

2. Development of technology for processing babassu fruit at the farm level would involve engineering studies to scale-down available peeling-separating-breaking equipment and adapting locally available charcoal kilns to facilitate recuperation of tar. Such developments should go hand-in-hand with market research to identify potential users of non-traditional babassu products, and study of alternative organizational and financial arrangements for fruit collection and processing.

3. Continuing research is needed on management of native stands, and studies of the most efficient crop and pasture species combinations in a

farming systems context. Trials examining the palm's productivity response under varying levels of soil fertility and water availability are also needed to serve as the basis for recommendations regarding appropriate environmental conditions to speed growth to maturity, improve the ratio of female to male inflorescences as well as the number of palms bearing fruit and the number of panicles per tree.

4. Since many factors affecting productivity appear to be genetically determined in babassu, research is needed to distinguish between environmental and genetic conditions affecting characteristics important to industry such as kernel content. To do so, seed specimens from prolific populations such as that of *Orbignya oleifera* in Pirapora, Minas Gerais described above must be secured before the palms are cut for crop and pasture development, a real threat in the Pirapora case, whose present population appears to be geographically restricted and endangered, and perhaps comprised of only a few thousand individuals.

5.6 Data/information base

The Brazilian National Corporation for Research on Agriculture and Livestock Husbandry (EMBRAPA), through its National Center for Genetic Resources (CENARGEN) and state-level activities in both Maranhão and Piauí has begun a broad-based programme of research and development with babassu and associated palms. A National Babassu Research Programme (PNP-Babaçu) has been established, with staff based in EMBRAPA's Special Unit for State-Level Research (UEPAE) in Teresina, Piauí, responsible for overseeing 9 local projects underway in 1984 on palm phenology, taxonomy, germination and seedling production, and forage combinations, among other concerns [6], and for disseminating results in its publication series. A bibliography on babassu literature has been published [5] as well as a collection of current and historical literature.

CENARGEN, with local resources as well as a USAID grant to the New York Botanical Garden (NYBG) has established an active Babassu Germ Plasm Bank in the Mid-North region, in collaboration with EMBRAPA staff and state agencies in Maranhão and Piauí. Specimens collected from other parts of Brazil and Latin America have been planted as a base for genetic improvement. Voucher specimens for seed are also retained in CENARGEN headquarters in Brasília, at the Museu Goeldi in Belém, and at the NYBG.

Data on babassu phenology, taxonomy, ecology and utilization were obtained recently by Anderson [2, 3]; economic study of babassu agroforestry systems is currently being carried out by the senior author who may be contacted for further information.

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