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JARI AT AGE 19: LESSONS FOR BRAZIL'S SILVICULTURAL PLANS AT CARAJÁS

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Introduction: Jari and Carajás

Jari, a 1.6 million ha estate on the Jari River on the northern side of Brazil's Amazon River (Figure 1), takes on new significance with the announcement of plans for mammoth silvicultural plantations in the Grande Carajás program area in Eastern Amazônia. Initiation of mining at Carajás, site of the world's largest high-grade iron ore deposit, provides the impetus for the Grande Carajás Program to finance development in a 900,000 km^2 area in the states of Pará, Maranhão and Goiás (Fearnside, 1986a). How Jari is faring 19 years after silvicultural planting began in 1968 is important because far larger silvicultural schemes would be needed to meet charcoal demand of pig-iron smelters planned for Carajás. Jari is famous as Amazônia's largest silvicultural plantation.

Interpreting its significance requires an understanding of the array of other economic undertakings at Jari: an irrigated rice plantation, a kaolin (china-clay) mine, a water buffalo herd in flooded grassland *(várzea)* areas, a modest cattle ranching operation in the unflooded uplands, and a sawmill.

In January 1982 Jari's original owner, D. K. Ludwig of Universe Tankships Corp., sold a controlling interest in the estate to a consortium of Brazilian firms now numbering 22. The new Jari (made up of three firms: Companhia Florestal Monte Dourado, Companhia Agro-Pecuária São Raimundo, and Caulim da Amazônia) is headed by the Brazilian mining magnate Augusto Trajano de Azevedo Antunes. The new Jari has made great strides to reduce financial losses and was able to claim an operating profit for the first time in 1985/86. Reports describing Jari "out of the red" are widely known in Brazil having appeared in *Veja* (8 January 1986), the country's largest weekly newsmagazine. *Newsweek* (11 August 1986) has also reported "the unmaking of a fiasco" at Jari. Unfortunately, the impression that large-scale silviculture is now a viable activity in Amazônia is misleading. Reasons include the "operating profit" not reflecting the cost of servicing Jari's debt, the operation having been sold to its current owners at a fraction of its original cost, and the unusual circumstance of a highly profitable kaolin mine compensating for losses in the silviculture sector.

The present paper is based largely on information obtained during a recent return to Jari (10-12 April 1986). Jari has changed in a variety of ways since previous visits (Fearnside and Rankin, 1980, 1982, 1985). Developments there give an idea of the complexity and uncertainty of silvicultural operations on the scale contemplated under the Grande Carajás Program. They also indicate changes, both good and bad, in the outlook for sustainability of the plantations at Jari itself. Jari's vast size makes the security of its future an important question for the region.

Changes Since "Jari Revisited" (Fearnside and Rankin, 1985)

A) Commercial Plantation Species

Since 1983, the share of the estate's plantation area occupied by *Gmelina* has declined in favor of *Eucalyptus* and *Pinus* (Figure 2), and the number of *Eucalyptus* species has increased. In addition to *E. deglupta* and *E. urophylla*, the estate's commercial stands now include *E. grandis*, *E. urograndis*, and some *E. pellita*.

Gmelina arborea

Jari's managers have been forced to further reduce the rotation time for the estate's premier species, *Gmelina arborea*. *Gmelina* was originally to be harvested on a 6 year cycle, but by 1983 the cycle had to be shortened to 5 years to avoid losses to the fungus *Ceratocystis fimbriata* (Fearnside and Ran-

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kin, 1985: 121). Jari now harvests its *Gmelina* at the young age of 3-4 years to avoid the fungus, which has become more severe. In the case of *Gmelina* grown from stump sprouts, or coppices, early cutting is also wise due to weak growth after the fourth year. Shortened rotations imply substantial increases in production costs: planting, weeding and harvesting operations have to be done regardless of rotation length.

The *Ceratocystis* fungus attacks coppiced *Gmelina* more severely than *Gmelina* planted as seeds or seedlings. Since coppiced *Gmelina* grows faster than trees planted from seed (in the first 4 years), Jari's managers hope that sufficiently resistant stock can be developed to allow use of the coppices. Coppiced *Gmelina* would also be advantageous on the more steeply-sloping sites to minimize erosion between crops.

Breeding continues in a yet unsuccessful effort to develop lines of *Gmelina* resistant to *Ceratocystis*. Jari's past successes in improving *Gmelina* growth form are being transferred to the plantations in the *Gmelina* that is not allowed to grow back as coppices. The limited size of the present seed orchard has created a shortage of improved seed stock. A 70 ha area in a commercial stand is now being thinned for conversion to an additional source of seed.

Gmelina is being innoculated with *Ceratocystis* fungus in some parts of the commercial plantations in an effort to select resistant stock. Experiments are also underway in which infected trees are cut and left in the plantations (rather than being removed) in order to see if this cheaper measure would be sufficient to control the fungus.

A new fungus has appeared at Jari, attacking 100 ha of *Gmelina* in October and November 1985. The as yet unidentified fungus caused leaves to fall off the trees, but the trees survived and the leaves have since grown back.

Applying fertilizers to commercial *Gmelina* plantations, begun in 1982 (Fearnside and Rankin, 1985: 123), has been discontinued. The cost of balancing nutrient removals will eventually have to be paid if production is to be sustained.

Bulldozing to remove stumps, known as "intensive site preparations," is being done at a rate of 3000-4000 ha/ year, which is as fast as Jari's current capabilities allow. At this rate it would take 25-33 years to destump the approximately 100,000 ha area deforested so far. Jari's managers do not plan to destump the steeply-sloping areas, where the erosion hazard is greatest. However, the staff fear that increasing cost of manual labor will eventually make unmechanized use of the steeply-sloping areas uneconomic.

Jari's silviculture staff acknowledge that they will not be able to plant more than a very few cycles of *Gmelina* on the steeply-sloping sites due to erosion. If management of the resprouts (coppices) proves impractical due to the *Ceratocystis* fungus, then these sites will either have to be abandoned or converted to a perennial crop (oil palm, etc.) or to a long-cycle rotation of hardwood species. Tests with perennial crops (cacao) and planted hardwoods (teak) were discontinued under the previous administration when they proved uneconomic (Fearnside and Rankin, 1980).

Jari already has abandoned *Gmelina* stands totaling 793 ha (226 ha planted from seed and 567 ha resprouted as coppices). Abandonment is the likely fate of an area of approximately 1500 ha in the Pacanarí sector located on "patio" soil, a very poor plinthosol (apparently Block 69-76). The staff believe that some of the abandoned *Gmelina* stands that were cut and then left unmanaged may yet produce at least a little useful wood, since the mill can accept very thin logs.

Pinus caribaea

Carribean pine *(Pinus caribaea)* is viewed with increasing enthusiasm by Jari's managers for an expanded role in the future. Growth of *Pinus caribaea*, now being planted on slightly better soils than before, has been good, in some cases with yields as high as those of *Eucalyptus*. Jari's managers report that good growth has been achieved on some (unvisited) sites with poor soil quality. One of these sites is on a sandy soil in its second rotation.

Pinus caribaea normally has slow growth in the first 3 years, after which the rate increases. *Pinus* has produced up to 14.5 m tons/ha/year in young plantations on the best plateau soils, but only around 8 m tons/ha/year in the areas to be harvested. Low yields are blamed on lack of adequate weeding during the transition phase. The best 1973 area (Block 43-73/86) produced 23 m tons/ha/year when harvested at the age of 13 years.

Attack of the fungus *Cylindrocladius deslupario* in *Pinus* first became a worry in 1984 when *Eucalyptus urograndis* (a susceptible species) was introduced on a commercial scale at Jari. The fungus is increasing steadily in the *E. urograndis* stands but is remaining at a stable level in *Pinus*. When this fungus attacks a tree the needles dry up but the tree is not killed.

Fires have caused no serious damage since 1983, despite dry weather. Fire is an inherent hazard in plantations of *Pinus* and has caused significant damage at Jari in the past (Fearnside and Rankin, 1980, 1985). As a precaution, Jari is now leaving wider firebreaks of native forest between plantation blocks.

The staff say that the problem of fires spreading into the plantations from slash-and-burn fields in squatter claims has diminished. The company has established a "Rural Settlement Nucleus" (NAR) to resettle squatters and has assigned three social assistants to the resettlement sites. The plantation staff state that the squatters have been accepting relocation and that burning in the community fields in the resettlement area is done after informing Jari staff so that precautions can be taken. I did not visit any of the resettlement sites. It is unclear how many of the 1500-2500 squatter families present in 1983 have accepted resettlement.

"Foxtailing" (the tendency to long branchless apical shoots) is still a problem in Jari's *Pinus caribaea*. Genetic material was selected in *ca.* 1978 from 50 of the best trees, but the progeny of these trees (being raised in Moro do Sol in the state of Minas Gerais) have not yet had sufficient time to produce seed for commercial plantations.

The need to keep the pulp mill supplied with chips has obliged Jari to harvest *Pinus* at the age of 9 years. The quality of pine pulp is highest at an age of 11 years, as the fiber length increases at a rate of about 5% per year in the 9-11 year age interval. Long fibers give resistance to tearing. The decision to harvest Jari's pine at 9 years rather than waiting longer therefore carries the opportunity cost of foregoing two or more years of growth with minimal expenses for weeding and other maintenance work and results in some sacrifice of product quality.

Jari's planning department classified 728 ha of *Pinus* stands as "abandoned" as of February 1986. In addition, an area of approximately 3000 ha where *Pinus* has grown poorly is being

TABLE I

PLANTATION AREAS AT JARI [(a)]

Year of planting	Gmelina from seed	Gmelina from coppices	Pinus caribaea	Eucalyptus deglupta	Eucalyptus urophylla	Eucalyptus urograndis	Eucalyptus pellita	Eucalyptus camaldulensis	Native species	Experimental	Commercial total
1970	0	0	0	0	0	0	0	0	0	14	0
1971	0	0	0	0	0	0	0	0	0	3	0
1972	0	0	0	0	0	0	0	0	0	56	0
1973	0	0	148	0	0	0	0	0	0	19	148
1974	0	0	270	0	0	0	0	0	0	0	270
1975	0	0	10	0	0	0	0	0	0	23	10
1976	34	0	238	0	0	0	0	0	0	12	272
1977	0	0	727	0	0	0	0	0	0	19	727
1978	0	0	4,595	0	0	0	0	0	0	49	4,595
1979	0	0	4,824	0	0	0	0	0	0	19	4,824
1980	12	0	732	263	0	0	0	0	0	63	1,007
1981	0	786	593	1,940	0	0	0	0	0	55	3,485
1982	0	365	1,234	7,461	166	0	0	2	0	27	11,819
1983	1,002	5,996	3,448	4,807	2,757	0	64	0	27	14	22,878
1984	1,005	2,100	6,792	0	7,392	142	0	0	130	101	14,003
1985	2,536	3,391	4,512	0	3,127	849	0	0	0	92	10,439
1986	0 (b)	0	0 (c)	0	0 (d)	0 (e)	0	0	0	0	0
Total	4,589	12,638	28,123	14,471	13,442	991	64	2	157	566	74,477

(a) Areas in hectares as of February 24, 1986.
(b) 4500 ha scheduled for planting in 1986.
(c) 7300 ha scheduled for planting in 1986.
(d) 460 ha scheduled for planting in 1986.
(e) 1840 ha scheduled for planting in 1986

converted to pasture following harvest of the pine in 1986 (Block 85-78). Silvicultural staff do not know why this first-cycle stand grew slowly but suggest as possible causes soil factors and competition from pasture grass initially interplanted with the pine. *Pinus caribaea* areas interplanted with cattle pasture when the pine trees were in their third through fifth year of growth have an additional weed problem from the remains of the pasture when the areas are used for a second cycle of pine. Jari's managers state that the conversion to pasture will be made because of the existing infrastructure (corrals and fences) at that site, not due to poor growth of the pine trees. The *Pinus* in the area scheduled for conversion to pasture grew at only about half the rate of trees on better sites. Jari's managers state clearly that planting pasture in former plantation areas is not contemplated as a sink for exhausted soils.

Eucalyptus deglupta

Jari has not planted *Eucalyptus deglupta* since 1983 and is now harvesting this species at the early age of 3-4 years so that the flow of chips to the mill can be maintained. Jari managers also point to the advantage of replacing *E. deglupta* stands with improved varieties of better *Eucalyptus* species. Jari's October-December dry period has a greater impact on the drought-sensitive *E. deglupta* than on other *Eucalyptus* species. *E. deglupta* also has the advantage of being resistant to the *Cylindrocladius deslupario* fungus, but other factors make phasing out *E. deglupta* a logical decision since the disease does not presently inflict severe damage.

Eucalyptus deglupta at Jari is plagued by the presence of polyphenols in the wood. These non-saponifiable residuals cause the core of the lower part of the trunk to become dark, readily apparent in the piled wood awaiting chipping. Some trunks, even though light in color when cut into cross sections for sampling, turn dark after a few hours indicating the presence of polyphenols. Were they not removed polyphenols would stain the pulp, lowering its market price. The US$6/m ton extra cost of removing polyphenols from *E. deglupta* will maintain the firm's reputation for top quality pulp until *E. urophylla*, which has no phenols, comes on line in 1988.

Jari maintains a stock of *E. deglupta* germplasm selected for low polyphenol content. This leaves open the option of returning to *E. deglupta* should fungal or other problems become severe in alternative species.

Pulp quality is lower from *Eucalyptus* grown on poor soils. This, combined with advantage of increased growth rate, may explain why all *Eucalyptus* species are fertilized at Jari. No other species is fertilized in commercial plantations at the estate.

Eucalyptus enters into conflict with *Gmelina* for the optimal time of year for harvesting. *Gmelina* is best harvested in the dry season because the steeply sloping clay soils often planted to this species have a higher potential for erosion and because machinery is difficult to use in these hilly areas during the rainy period. *E. deglupta* is also best harvested in the dry season due to the lower content of "extractibles" (impurities) that have to be removed from the pulp if harvested at this time. *Gmelina* also has more impurities in the rainy season, although the beige-colored im-

TABLE II

ROTATIONS AND YIELDS OF SILVICULTURAL SPECIES AT JARI

Species	Rotation (years)	Weight harvested with bark (m tons/ha)	Bark (% dry weight)	Wood yield (m tons/ ha/year)
Gmelina arborea	4	45-50	20	9.0-10.0
Eucalyptus deglupta	4	60-70	10	13.5-15.75
Eucalyptus urophylla	4	66-80.5	20	13.2-16.1
Pinus caribaea	9	120-130	24-25	5.0-5.5

TABLE III

WOOD GROWTH BALANCE AT JARI

Species	Area (ha)	Wood yield (m tons/ha/ year) (a)	Native wood supplement (% of mix)	Total wood (plantation & native) (m tons/year)
Gmelina arborea	17,227	9.5	5	172,270
Pinus caribaea	28,123	5.25	0	147,646
Eucalyptus deglupta	14,471	14.625	40	352,730
E. urophylla, E. urograndis & E. pellita	14,499	14.65	20 (b)	265,513
Other commercial & experimental plantations	725	14.65 (c)	20 (b)	13,276
TOTAL	75,200	9.92		951,435

(a) Midpoints of ranges in Table II.
(b) Guess (50% of *E. deglupta* value).
(c) Assumed equal to *E. urophylla* value.

CALCULATION OF SHORTFALL

Mill requirement = 3000-3500 m tons/day of chips
(midpoint = 3250 m tons/day)

Annual requirement (allowing for 2 week shutdown for repairs) =
351 days x 3250 = 1,140,750 m tons of chips (dry weight)

Annual shortfall = 1,140,750 — 951,435 = 189,315 m tons of chips

Shortfall from plantation sources = 189,315 x (1 — 0.156) = 159,782 m tons

Additional plantation area needed (at present configuration and yields) =
159,782 / 9.92 m tons/ha/yr average yield = 16,107 ha

Expansion needed as percentage of present plantation area =
16,107 ha / 75,200 ha = 21.4% increase

purities in *Gmelina* cause less problems than do the black ones in *E. deglupta.*

The density of *E. deglupta* at Jari is lower than that of *Eucalyptus* in Brazil's Central-South Region. To avoid the lower quality pulp that would result from using its *E. deglupta* in pure form, Jari has developed a mix of native species that includes 40% "capitarí (*Tabebuia insignis,* BIGNONIACEAE). The supplement of wood from native forests also significantly reduces the cost of supplying the mill's requirements for chips.

Jari had 1847 ha of abandoned *E. deglupta* as of February 1986. These stands had apparently been planted on inappropriate sites; no plans have been made for conversion of the areas to other uses.

Eucalyptus urophylla

The *Cylindrocladius* fungus attacks *E. urophylla,* but trees are not killed and growth reduction is apparently not great. *E. urophylla* suffers less attack than does *E. urograndis.* Currently there is more *Cylindrocladius* on the Amapá side of the Jari River than on the Pará side; some of the staff ascribe the difference to heavier clay soil on the Amapá side.

A bacterial disease caused by *Pseudomonus solonacearum* has appeared in *E. urophylla,* mostly in young trees. The bacteria attack the roots of the trees; the leaves turn yellow and the tree dies. The technical staff first observed symptoms in 1984. Since that time the disease has spread but has not reached alarming levels.

A lepodopteran larva attacked *E. urophylla* in 1985, but damage was reportedly not serious. A microhymenopteran attacked part of one block (Block 35) in 1985, but has not increased since. Neither of the insects has yet been identified.

E. Urograndis

E. urograndis is a hybrid of *E. urophylla* males and *E. grandis* females produced by interbreeding in open plantations. Since the crossfertilization is not done under strictly controlled conditions, the "*E. urograndis*" stands contain a scattering of individuals of the parent species in addition to the hybrids.

E. urograndis is the most susceptible to the *Cylindrocladius desluparío* fungus of the major commercial *Eucalyptus* species at Jari. The effects are worse in the young trees. The attack is worse in the rainy season. The fungus slows the growth rate of the trees without killing them.

Eucalyptus cancre (the fungus *Diaportha cubensis*) is the Achilles's heel of *E. grandis.* Cancre attack is not evident in the hybrid at Jari.

E. pellita

Jari has *E. pellita* on a small scale: 64 ha were planted in 1983 (in parcels spread throughout the estate), but Jari's managers are now postponing full commercial-scale planting until they see the effects of the *Cylindrocladius* fungus. In one 12 ha plot of *E. pellita* 16% of the trees were attacked in the first year, and some trees died. Nevertheless, in 1986 the experimental parcels in the estate were augmented by an additional 200 ha.

B) Experimental Plantation Species

Jari's ability to weather future biological problems will be largely determined by the availability of alternative silvicultural species. Adequate testing of potential species, carried out at the site, is the best means of minimizing the risk of an inappropriate choice. The following species are under testing:

E. grandis: Jari installed a 14 ha experimental planting of *E., grandis* from a location in Australia believed to be similar to Jari. Trees from this procedence are thought to offer a good chance of resisting the cancre that often attacks plantations of this species. Finding alternative *Eucalyptus* species is a sufficiently high priority at Jari that 14 ha of one-year-old commercial pine plantation were sacrificed to install the experiment in 1985.

E. camaldulensis: Although this species is sometimes used for pulp (United States, NAS 1980: 126) the only potential use for it at Jari would be for firewood. Despite enthusiasm among the research staff under Ludwig and good growth in experimental plantations (Fearnside and Rankin, 1982), the species is no longer under consideration for commercial plantation due to poor pulping characteristics.

E. tornelliana: This species grows well at Jari, quickly shading out the undergrowth. However, it is not a good pulping species and only can be used for firewood.

E. brassiana: Growth since testing began in 1984 has not been good.

E. pillularis: A test plot of this species planted in 1985 is too young to be evaluated.

Pinus oocarpa: This species has poorer growth than *P. caribaea* in the first two years but then catches up and grows faster. *P. oocarpa* must be maintained with more thorough weeding than *P. caribaea* until it reaches a height of two meters (in approximately two years). *P. caribaea* can survive even if left in a heavily weed-infested stand with only the tips of the trees showing. *P. oocarpa* often starts its growth lying down or in other ways that produce poor form. It also has more branches and side sprouts near the ground. The staff consider *P. oocarpa* to be more susceptible to the *Cylindrocladius* fungus than is *P. caribaea*. It also has high variability in the growth among individual trees — not a good characteristic for plantations, but one that allows rapid genetic selection. *P. oocarpa* has the advantage of very little foxtailing as compared to *P. caribaea*. The species is considered a potential option for commercial planting should a change be desirable, but Jari has no immediate plans for such a change.

Anthocephalus chinensis: This species, which had been growing well in an experimental stand on fairly good soils (Fearnside and Rankin, 1980), died mysteriously in 1984 at an age of approximately six years. No disease symptoms, insect attack, or other problems were evident.

Casuarina: Testing of this Asian legume was enthusiastically initiated under the previous management in about 1979. The species is only usable for firewood. Experiments are not continuing.

"Pará-Pará" *(Jacaranda copaia):* This native species has good growth but requires relatively fertile soil. Many but not all trees are attacked by *Hysipyla* shootborers (pit moth larvae) (Fearnside and Rankin, 1980). Small-scale experiments continue.

"Mungubeira" *(Bombax munguba):* Experiments that were initiated shortly before the end of Ludwig's tenure have not been pursued. Mungubeira is a native of the Amazônian *várzea* and grows well there.

"Taxí Preto" *(Triplaris filipensis):* A 1 ha plot of this native species was planted in 1985. The young trees suffered some damage by grasshoppers and ants.

To summarize the status of the search for new species, both exotic and native, Jari has a number of species under testing, a few of which have given reasonably positive results at the site. No species is currently attractive enough to suggest any likely changes in the choices for commercial plantations over the next few years, but some are sufficiently well adapted that they could be called upon should biological problems arise that are highly damaging to *Pinus caribaea* or the current *Eucalyptus* species. No such safeguard exists in the case of Jari's hallmark species: *Gmelina arborea*. No native species are under serious consideration for commercial planting.

C) Silvicultural Management

One casualty of the cost-cutting measures during Jari's financial squeeze has been the recycling of some of the pulp mill's residuals to the plantations. In the long term the outflow of nutrients through biomass harvesting, soil erosion and other pathways must be

TABLE IV

SUPPLEMENTARY WOOD SOURCES AT JARI (1985/86)

Source	Note	Aproximate weight (10^3 m tons/year)
Deforestation for plantations	(a)	26.25
EMBRAPA experiments	(b)	0.54
Capitarí *(Tabebuia insignis)*	(c)	84
Purchase of *Pinus caribaea* chips	(d)	78
TOTAL (10^3 m tons)		188.79
PERCENT OF TOTAL PULPWOOD	(e)	17%

(a) Approximately 3000 ha felled for plantations in 1985. Average wet weight biomass of logs = 350 m tons/ha (Fearnside and Rankin, 1985: 125), or approximately 175 m tons/ha dry weight. The dry weight pulped per hectare felled is approximately 8.75 m tons, since 5% of the species are used for pulp; these species are assumed to represent the same percentage of harvested biomass. This is consistent with the 10% of biomass used for pulping in 1983 (Fearnside and Rankin, 1985: 125) when twice the present number of species were used for pulping.

(b) total amount harvested = 18 x 10^3 m^3; average density = 0.6; assume 5% used as in note (a).

(c) 4 month *Eucalyptus* run (= 120 days) x 700 m tons capitarí/day.

(d) 390 x 10^3 m tons chip demand (From Table V) x 20% supplied from purchases (1985/86 value).

(e) 1,140,750 m tons for operation at full capacity (see Table III).

balanced by inputs. The practice initiated in 1983 of returning some of the nutrients removed, although small in scale, was an important sign of recognition of this limitation.

Leaf cutter ant *(Atta)* control is now more effective than it was under the previous management. Mirex baits are still the most important component: Jari now uses 50-60 m tons per year of Mirex (as compared to 100-120 m tons/year before 1983): The Mirex is applied to a larger area than previously, but the area has a lower infestation of the ants. Mirex is applied to all plantations, whether they are to be harvested that year or not. Baits are also placed in a 100 m swath in the forest around all of the plantations. Mirex is put out in the dry season, and is most effective just after burning when there is nothing else for the ants to carry away to feed the fungal gardens in their nests.

Leaf cutter ant control in the rainy season relied on the liquid insecticide Arbinex. From 1983 to 1986 Jari used 10 thousand liters per year of the poison; new Brazilian environmental regulations now prohibit its use. Methyl bromide gas, which was pumped into the leaf cutter ant nests as a part of the *Atta* control program during Ludwig's tenure, has since been discontinued as overly expensive.

Burning, a necessary part of the site preparation process for plantation establishment, failed over a total of 3000 ha 1985. Due to the onset of the rains, burns failed in a 1500 ha area that had been felled in Felipe (Amapá). Native forest wood was removed from 1200 ha before the rains precluded further work; secondary forest growing up on the site will be cut and burned for plantation establishment in 1987. Two areas in Pará did not burn either. Heavy rains preventing burning in some years severely affects cattle ranchers and small farmers throughout Amazônia (Fearnside, 1986b, and) Jari's failure to burn a substantial portion of its clearing in 1985 will save money in the short term since the expense of planting these areas was deferred but will prolong the period of insufficient plantation area to meet the mill's wood demands.

Improved knowledge of the estate's soil and weather, and of the requirements of the species planted, is continuing to reduce the risk of major management blunders. The importance of the high variability of Amazônian soils has been amply demonstrated at Jari, from the initial catastrophic mistake of planting large areas of *Gmelina* on sandy soils (Fearnside and Rankin, 1980) to the subsequent adjustments reflected in the areas abandoned or converted to other uses. A top priority of Jari's current research effort is a detailed soil survey of the estate. Once this information is in hand, it is hoped that the growth records of plantations on the sites will yield a series of regressions for more accurate prediction of plantation yields on different sites. This is clearly essential for reliable long-range planning.

Jari's increased number of planted pulp species represents an important safeguard against biological problems in any given species, as well as a means of making better use of the variety of soil qualities present in the estate. Planting a still broader range of species would be highly advisable.

Breeding of improved silvicultural varieties continues. The potential gains from investment in genetic improvement are very great: because the cost of production is so high relative to the price received for the estate's pulp, even small increments in the yield per hectare represent large percentage gains in profits (or cuts in losses).

Silvicultural treatments are being readied in preparation for possible long-range changes in Brazil's labor economy. Motorized mowers are now weeding some stands of *Pinus* and *Eucalyptus* (but not *Gmelina).* The staff are concerned that the presently very low wages in Brazil for manual labor could rise sharply, significantly increasing the company's costs. Such changes in manual labor costs have forced abandonment of silvicultural plantations in some other countries (see Fearnside and Rankin, 1980). The company rather have a smaller number of better-qualified and better-paid machine operators settled with their families than a large number of migrant laborers for manual weed control. Migrant laborers come with diseases such as malaria, filling up the hospitals and creating social problems. Nor will their children ever provide a settled pool of qualified labor. Antunes backs the effort to create a pool of skilled labor rooted at Jari and has agreed to pay for a secondary school in Monte Dourado to give agronomic and silvicultural training to local youth.

Rooting staff at Jari is important at all levels in the company hierarchy. Turnover in the technical staff has been extremely high. Of the 22 persons in a 1982 photograph of the technical staff at the pulp mill, only two were still at Jari by 1986. Technical staff turnover has been due largely to low salaries, now-one third to one-half the level of Jari's 1980 salaries in real terms. Other firms have been able to tempt Jari employees away, sometimes taking entire departments at once. Although salaries in many Brazilian government institutions have fallen even further than Jari's salaries during the same period, the private sector competes successfully by offering slightly higher pay. In addition, Jari would have to offer higher salaries to hold employees who would rather live near a large urban center.

TABLE V

CALCULATION OF CONTRIBUTION FROM NATIVE WOOD AT JARI

Species	Pulp production in 1984/85 (a) (10^3 m tons)	Chips required (10^3 m tons) (b)	Supplement as percent of plantation contribution (c)	Supplementary wood (10^3 m tons)
Gmelina arborea	82	355.3	5.263	18.7
Pinus caribaea	90	390.0	0	0
Eucalyptus deglupta	42	182.0	25 (d)	45.5
TOTAL	214	927.3		64.2

(a) From Table VII

(b) Calculated from ratio of chip demand to pulp production = 3250 m tons chips : 750 m tons pulp (= 4.33 : 1)

(c) Derived from percentage of mix given in Table III:
$x = p/(1 - p)$ where:
x = supplement as proportion of plantation contribution
p = supplement as proportion of mix (total wood)

(d) Contribution from capitarí *(Tabebuia insignis)* only; some upland forest trees are also used.

Although the plantations were begun in 1968, it is misleading to assume that the firm has the benefit of 19 years of silvicultural experience at the site. The high turnover in personnel has resulted in virtually no living memory of the earlier years among those in positions of technical responsibility. I was frequently surprised to find myself called upon as a source of information about what had been done under the previous management.

High turnover can be particularly detrimental to long-term research projects, since silviculture experiments by nature take years to produce results. Adequate record-keeping is essential to insure against the loss of information from past experience in the face of staff turnover. The formal experiments set up by the research department are usually well recorded, but a substantial body of research information is generated informally from spur-of-the-moment initiatives in the forest management department. These research initiatives are a healthy way of quickly obtaining rough information on the response to variations in fertilizer application, weeding, and other management techniques. When informal trials of this type give promising results, the research department follows them up by formal controlled experiments. Examples include fertilizer use in compacted soil in former log storage decks and the use of more economically handled tubes for planting seedlings in the nursery. Much of the information gained from informal trials is lost when the staff leave Jari.

The new Jari has had the benefit of a stable management at the top, in sharp contrast to the estate's past history. While Ludwig hired and fired over 30 directors over the course of his 14-year tenure, a single director led the enterprise from the time control passed to the present consortium in 1982 until he stepped down in July 1986. The former director will continue to participate in Jari's management in an advisory capacity.

D) Use of Native Forest

Fewer species of trees from the native forest are used for pulp at Jari than previously. Only 5% of the native species are for pulping: the list has been reduced from 80 species used in 1983 to 40 species in 1986. Only those species with long fibers, which resist tearing, are now used. The heavier native woods break the lighter *Eucalyptus*.

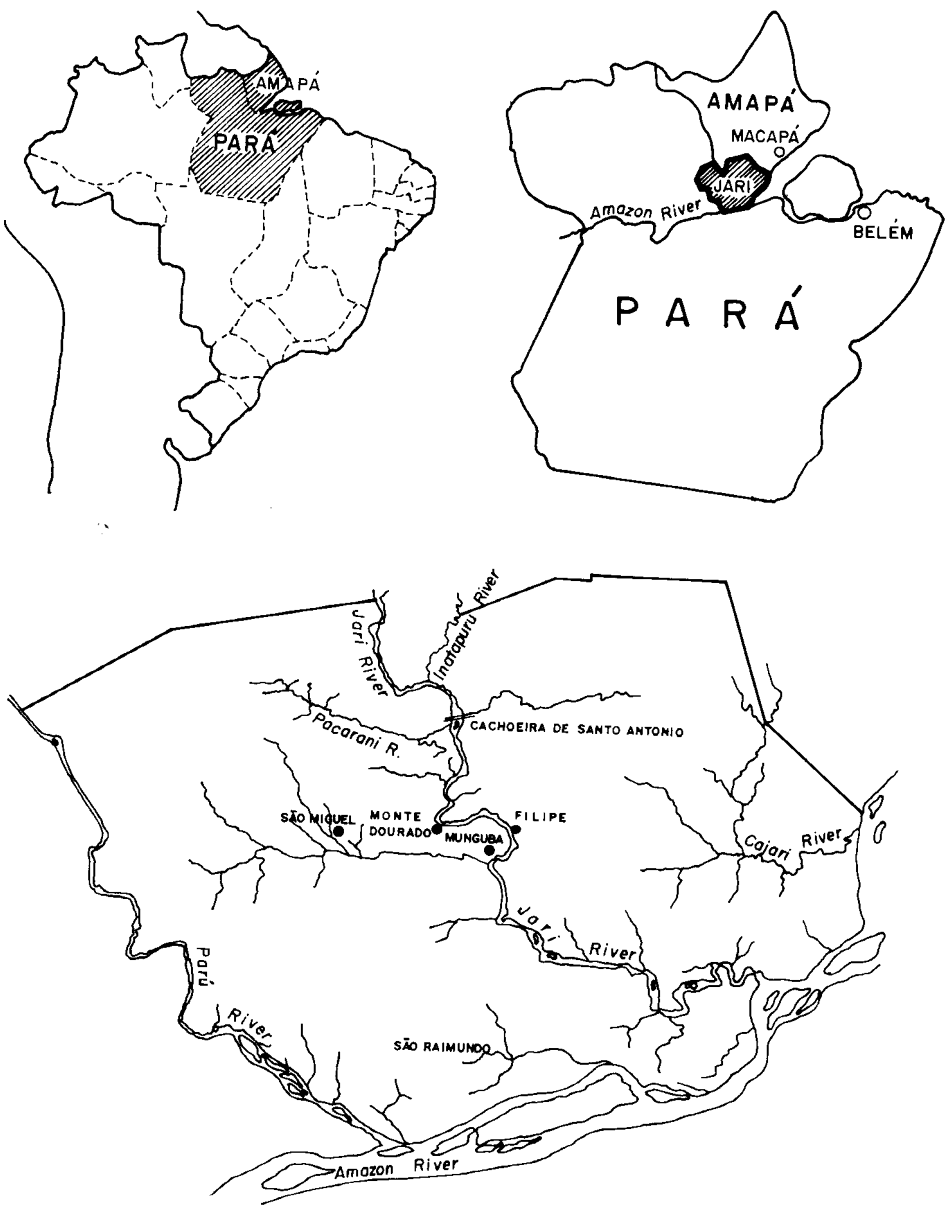

Fig. 1. Location and features of Jari.

A significant addition to the *Eucalyptus deglupta* pulp has been wood from "capitarí" *(Tabebuia insignis)*, a tree obtained from natural forest in the floodplain along the Igarapé Ipitinga, a tributary to the Jari River near its confluence with the Amazon. Harvest is from December through July, during which time the mill consumes daily 700 m tons wet weight of the species. An 8000 ha tract of capitarí is being cut over the 1985-1987 period, 5000 ha of which had been cut by April 1986. A network of canals has been constructed to float the logs to a central collection point where they are grouped into rafts of 25,000 logs for the 3-day trip to the pulp mill. The cut areas are not replanted, nor are they converted to water buffalo or rice. Capitarí makes up 40% of the mixture in Jari's *Eucalyptus deglupta* pulp. Capitarí has thicker fibers and thinner walls than does *Eucalyptus*, resulting in better quality pulp than would be obtained from pure *Eucalyptus*. The estate's "Jarilyptus" pulp is therefore not considered to be *Eucalyptus* in international markets, but is classified as a different product with different uses.

Some native "mungubeira" *(Bombax munguba)*, another várzea tree, is also used. Its long fiber is used to improve the mix so that stronger cellulose is produced.

An additional supplement to wood supply comes from upland forest management experiments being conducted at Jari by the Brazilian Enterprise for Agriculture and Cattle Ranching Research (EMBRAPA). A selective felling experiment has established 48 plots of 0.25 ha each at Jari (12 ha total). However, much larger areas are managed for other purposes under the Jari/EMBRAPA agreement: 400 ha were designated in 1981 for firewood management; a 400-ha pulp-management area was established in 1981, and a 400-ha mixed-management area was established in 1982. In 1985 the first measurements were made in the management areas and in a 300-ha control plot in uncut native forest. An additional 933 ha of forest is directed to cellulose production through selective felling, with measurement parcels established within the tract.

The EMBRAPA selective felling experiments provide a significant supplement of wood for the pulp mill and power plant without the expenses of either planting silvicultural species in cleared areas or replacing the harvested trees in the forest areas. In November and December 1985, for example, 500 ha were selectively harvested among the three treatments, yielding 18,000 m^3 of wood. The harvesting scheme results in a maximum amount of wood being cut: of the 500 ha, 404 ha (81%) were cut at the highest level of intensity (removal of 35% of the average 166 m^3/ha total, or an average of 61 m^3/ha). The experiment itself was limited to 3 blocks of 48 ha each (144 ha total), with harvesting intensities of 15, 25 and 35%. All of the remainder of the 500-ha tract was harvested at the highest (35%) intensity level. EMBRAPA has also experimented with clearfelling: an area was cut in the dry season of 1985, logs were removed and branches left on the site, which was not burned. A secondary forest regrowing on the site is to be monitored to assess the utility of the species.

Since over 90% of Jari's upland forests are still intact, these forests are a major potential resource for the company. A tree species survey is underway beginning with areas that are topographically appropriate for future plantations. Jari maps indicate roads to three plateaus where no plantations have been installed. Forest inventories are being done on all such plateaus. By April 1986 Jari's research department had surveyed 4416 ha of forest in strips 80-100 meters wide, tagging 5800 trees and making botanical collections of 558 species.

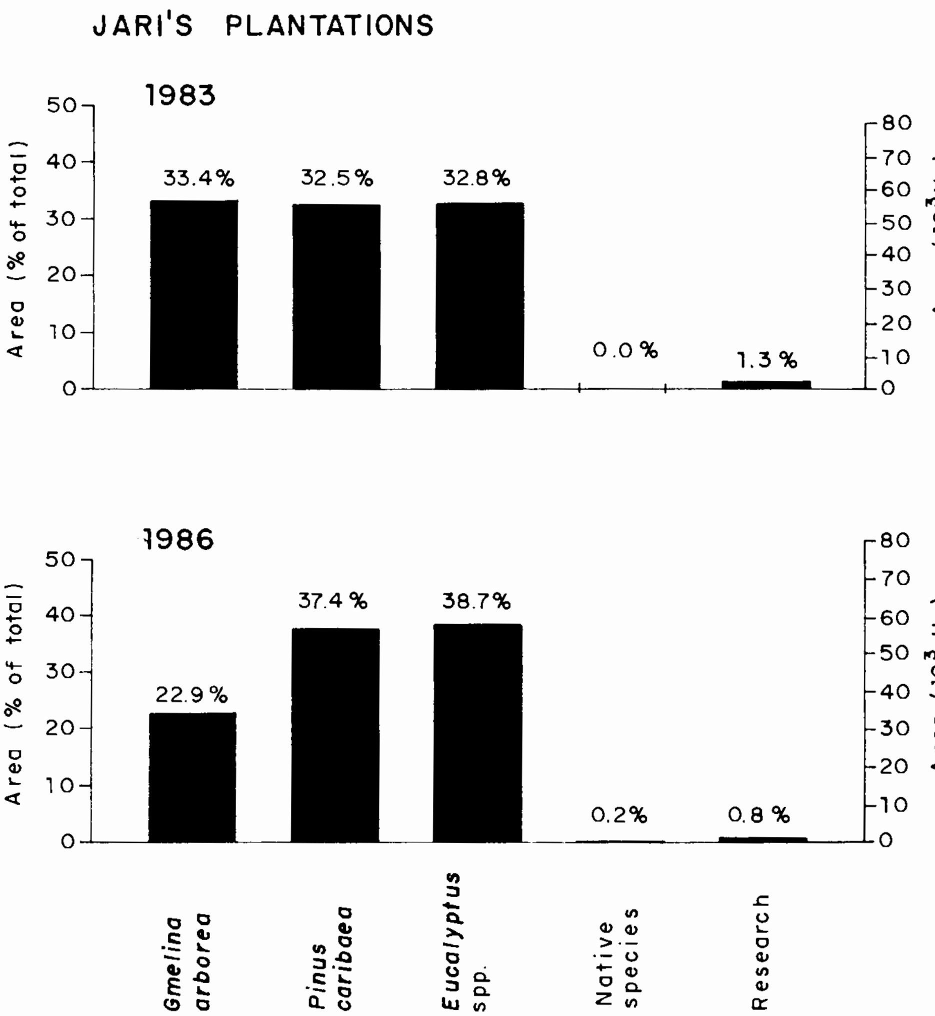

Fig. 2. Shift in silvicultural species at Jari.

E) Supplementary Wood Purchases

Jari purchased *Pinus caribaea* chips from AMCEL, a silvicultural company in Santa Isabel, Amapá, which supplied about 20% of the pine used in that phase of the pulp mill run in 1985/86. This also represents about 20% of the output of AMCEL, which will soon begin exporting pine chips to Europe. A contract has been signed assuring a supply of supplementary chips to Jari for the next three years. AMCEL's 30,000 ha *Pinus caribaea* plantation provides a measure of security to Jari, since AMCEL is another Antunes company. Jari staff emphasize that the full international market price was paid to AMCEL for the pine chips purchased. A smaller amount was apparently also bought from Georgia Pacific, which has a 3000 ha *Pinus caribaea* plantation in Portel, Pará.

F) Other Jari Operations

Irrigated Rice: Ludwig's irrigated rice scheme at São Raimundo was bought by the Jari consortium in 1984, two years after the silviculture and mining operations changed hands. The goal of expanding the rice operation to cover 14,000 ha, of which 12,700 ha would be cultivated, will not be reached in the near future. In 1986 a modest expansion of 650 ha, possible within the present system of dikes and canals, will bring the total cultivated area to 4,150 ha. Most of the area is harvested twice a year, but some is harvested three times — the mean being 2.3 harvests/ha/year.

The 1986 budget includes funds for constructing a canal to

TABLE VI

PROJECTED WOOD AVAILABILITY AT JARI

Item	Year ready to harvest	Gmelina (from seed & coppices)	Pinus caribaea	Eucalyptus deglupta	Eucalyptus urophylla	Eucalyptus urograndis	Eucalyptus camaldulensis & pellita	Native species	Experimental	Total
Area (ha)	1986	1,197	1,393	9,664	166	0	2	0	146	12,568
	1987	6,998	4,595	4,807	2,757	0	64	27	49	19,297
	1988	3,105	4,824	0	7,392	142	0	130	19	15,612
	1989	5,927	732	0	3,127	849	0	0	63	10,698
Wood from plantations (m tons)	1986	55,119	74,534	601,409	9,728	0	117	0	27,115	767,927
	1987	265,924	96,495	281,210	161,560	0	3,750	1,582	6,461	937,601
	1988	117,990	227,934	0	433,171	8,321	0	7,618	2,505	797,540
	1989	225,226	34,587	0	183,242	49,751	0	0	8,306	501,113
Wood from native forest (m tons)	1986	2,901	0	400,940	2,431	0	29	0	6,754	413,075
	1987	13,996	0	187,479	40,390	0	938	396	1,615	244,816
	1988	6,210	0	0	108,292	2,080	0	1,904	626	119,114
	1989	11,854	0	0	45,810	12,438	0	0	2,076	72,179
Total pulpwood (m tons)	1986	58,020	74,534	1,002,349	12,159	0	146	0	33,768	1,180,997
	1987	279,920	96,495	468,689	201,950	0	4,688	1,978	8,076	1,182,417
	1988	124,200	227,934	0	541,464	10,401	0	9,522	3,131	916,653
	1989	237,080	34,587	0	229,053	69,189	0	0	10,383	572,292

		shortfall or surplus	quantity (m tons)	production as percent of need (a)
Wood availabiliy	1986	surplus:	40,247	104%
	1987	surplus:	41,667	104%
	1988	shortfall:	224,097	80%
	1989	shortfall:	567,458	50%

(a) Mill need = 1,140,750 metric tons dry weight of pulpwood chips per year.

bring water to the paddies from the Amazon River. Previous experiments had shown the advantages of using this nutrient-rich water source instead of the present water from the Ariaôlos River.

Rice production cost per ton is US$205 (direct costs only), plus US$133 per ton in indirect costs (administration, etc.), giving a total production cost of US$338/m ton. The price received in Belém is US$350/m ton, but the additional expenses of freight to Belém, taxes and comissions reduce the net amount received by Jari to US$ 305/m ton. The loss of US$33/m ton implies a financial drain of US$990,000 for the 30,000 m tons of rice produced in 1985.

All of the rice is sold within Brazil, at prices frozen under the country's "Plano Cruzado" economic package. Since international rice prices are higher than domestic prices, the company has lost money due to the requirement to sell the rice production domestically. Pulp prices, by contrast, are relatively low on the international marketplace, giving Jari an advantage on the portion of the pulp production sold within Brazil.

The research activities at the rice plantation are now carried out under a cooperative agreement with EMBRAPA. This is an essential element in assuring the ability of the operation to counter new biological problems in the future. Research at the rice project had been discontinued completely in the final two years of Ludwig's tenure.

Kaolin mining: Jari's kaolin (china-clay) mine has increased its output by expanding the number of settling ponds for separating the kaolin from the slurry that is piped from the minesite at Felipe (Amapá) to the processing plant at Munguba (Pará). The mining company (CADAM) has increased the pace of digging into Jari's open-pit mine and modified the procedures used at the processing plant in order to recover a higher percentage of the material.

Sawmill: Jari's sawmill continues to saw lumber from the valuable tree species encountered as land is cleared for plantations. The sawmill remains a relatively minor part of the enterprise.

Water Buffalo: The herd of 6800 water buffalo at Jari in 1983 increased to 9300 by 1986, spread over 50,000 of the 70,000 ha of natural flooded grasslands at Jari. Jari plans to triple the buffalo herd to 30,000 head, which would occupy all of Jari's flooded grassland area with the exception of the part planned for expansion of the rice project. Water buffalo will occupy the entire length of the Amazon River frontage of Jari, from the mouth of the Parú River to the mouth of the Cajarí River, in addition to the estate's islands in the Amazon River (see Figure 1).

The water buffalo raising scheme includes a milk and cheese production program established in late 1984, which is currently producing 1000 liters of milk per day (including butter and cheese). The cheese-making facilities have been moved to the Camanduí island in the Amazon river. The new system has a decentralized network of corrals atop earth-fill hills. During the high-water period, these artificial hills become small islands, each with an area of 1200 m^2. The earth-fill hills replace the traditional "marombas" — raised wooden platforms where the cattle are penned during the flood season. The remaining marombas at Jari will eventually be replaced by the earth-fill islands. The cowboy in charge of each island is provided with a house built over the corral. The houses have better sanitation and other facilities than most traditional floodplain residents enjoy. The cowboy's wife is responsible for making butter from some of the milk. Jari had six of the raised corrals as of April 1986 and planned to have two more by the end of 1986.

The earth-fill islands include a fish culture scheme still in an experimental phase. A hole is left in the center of each island, creating a pond. Excrement from the water buffalo in the corral fertilizes the pond, where aquatic plants (known locally as "mururé") serve as food for two species of forage fish (known locally as "tamuatá" and "jijuna"). These fish are eaten by the commercial species (pirarucú" *(Arapaima gigas)*. Research on the fish culture scheme has been underway since 1983 in a cooperative arrangement with EMBRAPA.

There is also a small experimental herd of 50 water buffalo in the *terra firme* (uplands) area near São Miguel. This operates under a cooperative agreement with the Faculty of Agrarian Sciences of Pará (FCAP).

Upland cattle: Jari currently has 2000 head of bovine cattle in *terra firme,* mostly near São Miguel. The area of pasture will expand by 3000 ha to take advantage of installations, allowing the total herd to be augmented to 7000 head. Jari has a demand for 500-600 head/month for meat supply. A herd of 35,000 head would be needed to supply this, including females kept for milk and cheese.

The upland cattle herd is no longer being managed for on-site reproduction. Heifers are bought and fattened. The remaining cows of good quality continue to be bred, and their offspring will be bred, but the firm's waning interest in the breeding phase means that this will fade out over a few years. Breeding would require more land and effort.

Establishment of new interplanted stands of pasture with *Pinus caribaea* was discontinued in *ca.* 1982 for a variety of reasons (Fearnside and Rankin, 1985). The cattle have since been removed from all of the previously established interplanted stands due to the pine's advancing age.

TABLE VII

FINANCIAL BALANCE IN JARI'S SILVICULTURE SECTOR (1984/85)

Receipts:

Pulp species	Market	Quantity (10^3 m tons)	Price (US$/ m tons FOB)	Value (10^3 US$)
Gmelina arborea	Export	66	267	17,622
	Domestic	16	331	5,296
Pinus caribaea	Export	48	249	11,952
	Domestic	42	256	10,752
Eucalyptus deglupta	Export	31	267	8,277
	Domestic	11	331	3,641
		214		57,540
Production costs (exclusive of debt service)				— 104,790
		LOSS IN SILVICULTURE SECTOR		= 47,250

Jari's upland cattle pastures are of the species *Brachiaria humidicola,* which was promoted throughout the Brazilian Amazon by EMBRAPA in the late 1970's. An increasing attack of the homopteran bug *Deois incompleta* (known locally as "cigarrinha") has since led EMBRAPA to recommend *Andropogon guianensis* instead. The bugs are a serious pest on the Belém-Brasília Highway in Pará and on the Cuiabá-Santarém Highway in northern Mato Grosso, but have not yet become a problem at Jari. Jari's ranching department says that its *Brachiaria humidicola* pastures have to be manually cleaned of woody second growth every year and replanted every 4 years.

Jari's Wood Shortage

Jari's mill uses 3000-3500 m tons/day of chips for pulping when operating at its 750 m tons/day nominal capacity. Chips required for firewood have so far been supplied entirely from native forest. The balance between wood demands and the growth of the plantations is essential in evaluating the project's future.

A rough calculation of the growth of the plantations can be gained from the midpoint areas of the present complex of each species and age class (Table I). Using the midpoint of the yield range for each species (Table II) one can calculate the approximate amount of wood growth in the estate's plantations (Table III). In order to bring plantation growth and wood demands into balance the plantation area would have to be expanded by 21.4%, assuming the same present percentage of each silvicultural species and the present supplement of native wood.

The wood balance over the next few years will be critical because Ludwig planted little in the last years of his tenure. The first trees planted under the new administration will come on line in 1987. In 1985 the company was racing to obtain enough wood to keep the mill from stopping. Measures included gleaning previously felled areas for logs that could be used for firewood in the power plant and the early harvest of stands. The mill wood demand was lower than usual: for reasons unrelated to the shortage the pulp mill operated at below capacity for several months, and then stopped operating altogether for one month during which repairs were effected. (1)

The availability of pulpwood over the 1986-1989 period can be roughly projected (Table VI) based on the plantation areas and age classes (Table I) and the rotations and yield midpoints for the major species (Table II). Several optimistic assumptions are made in the projection as estimates of the contributions of the species and age classes not included in Table II. (2) The projection indicates that Jari will have enough wood to supply its pulp mill in 1986 and 1987, but that in 1988 and 1989 there will be a severe shortfall. In 1989 the estate would only produce half of its pulpwood needs. The shortage in 1989 is approximately twice as severe as it would have been if bad weather had not prevented the estate from burning 3000 ha in 1985.

Jari's Financial Situation

Jari has achieved a significant improvement by eliminating its operating losses. Company oficials say that in 1982/83 Jari had an operating loss of US$87 million. Operating losses fell to US$23 million in 1983/84, and in 1984/85 the firm had neither an operating loss nor profit. A small operating profit is expected for 1985-86. Operating profits and losses do not include the cost of debt service — the payments of interest and principal on money owed to creditors. These costs must be substantial: Jari's debt at the time of Ludwig's (1982) sale was estimated to be US$300 million (*Isto É*, 21 May 1986), to which must be added a US$25 million loan obtained by the new owners in 1984 (Pinto, 1986: 210).

Jari's operating costs are high in part due to its vast infrastructure, including 3500 km of roads, not counting secondary roads in the plantations. For comparison, the Transamazon Highway route within Amazônia totals only about 3000 km. Expansion of the plantation area to bring growth and wood demand into balance will require further increasing this infrastructure.

Low pulp prices have been a major financial strain on Jari. The world pulp shortage that Ludwig originally foresaw raising pulp prices to US$700/ton in the 1980's has never materialized. Instead the pulp market declined to a low in 1985. The price of pulp in 1986 was around US$400/m ton, representing an improvement over 1985 market conditions but still not allowing the silviculture sector to meet its operating expenses from pulp sales.

The breakeven point used as a rule thumb at the pulp mill is US$450/ton for all three species. Since the price received has been in the neighborhood of US$400/ton, the difference represents a subsidy from the other company operations, especially the kaolin mine. Even the US$450 rule of thumb appears to underestimate the real cost of production. The financial sector's records indicate a total cost of US$ 104,790,000 in 1985, when 214,734 m tons of pulp were produced, giving a mean cost of US$488/m ton of pulp (Table VII).

When receipts are calculated by species (Table VII), the 1985 total comes to US$ 57.5 million. Since production costs (exclusive of debt service) were US$104.8 million, the silviculture sector lost US$47.2 million during the year, or US$5394 per hour. Only 55% of the production costs were recovered from the sale of pulp. Were debt service and long-term investments included, the financial drain from the silviculture sector would be substantially greater.

TABLE VIII

CHARCOAL DEMAND FOR GRANDE CARAJÁS COMPARED TO YIELDS AT JARI

Information on Grande Carajás charcoal scheme:	
Number of pig-iron plants approved: (a)	7
Annual charcoal demand for the pig-iron plants already approved:	705,000 metric tons
Mean charcoal demand per plant:	100,710 metric tons
Total number of pig-iron plants planned:	20
Conversion efficiency of wood to charcoal (mean of 4 conventional methods): (b)	0.23 metric tons of charcoal/ metric ton of dry wood
Information on the Jari Project:	
Mean yield of *Eucalyptus deglupta* at Jari (dry weight):	14.65 metric tons/ha/year
Area of managed plantations at Jari:	75,043 ha
One can calculate:	
Annual demand for charcoal: (c)	2,396,230 metric tons
Annual demand for wood: (dry weight)	10,418,390 metric tons
Area of *Eucalyptus* plantations required:	711,752 ha
Number of times the area of the plantations at Jari necessary to supply approved and planned plants:	9.5 times

(a) These are the 7 plants described in Brazil, SEPLAN/PGC/CODEBAR/SUDAM, 1986. Executive Secretary of the Grande Carajás Program (PGC) stated in May 1986 that 8 plants had already been approved (F. S. B. Ferreira, personal communication, 1986).

(b) Circular metalic kilns (0.19), rear-fired ("hot-tail") ceramic kilns (0.20), and ceramic surface kilns with 5 m diameter (0.27) and 8 m diameter (0.24). Tunnel kilns still under development can reach an efficiency of 0.33.

(c) Charcoal demand of industries already approved: 7 pig-iron plants = 705,000 metric tons/year; 2 iron alloy plants = 300,000 metric tons/year; 2 cement plants = 82,000 metric tons/year (Brazil, SUDAM/CODEBAR, 1986: 3). Approximate demand of 13 additional pig-iron plants awaiting approval = 1,309,230 metric tons/year.

The rice project partially offset losses from the silviculture sector. In 1985 Jari produced 30,000 tons of rice at a cost of US$1,592 million (US$53.07/m ton) and sold this production for US$2,812 million (US$93.74/m ton), yielding a gross profit of US$ 1,220 million.

The bulk of the subsidy to the silviculture sector has come from the highly profitable kaolin mine. CADAM (Caulim da Amazônia), the company running the mining operation, maintains a separate accounting office from the rest of Jari. One can deduce from Jari's achievement of an overall operating balance of neither profit nor loss that the 1984/85 contribution of the kaolin mine was approximately equal to the loss from the silviculture minus the profit from the rice, or US$47.2 — 1.2 = US$46 million.

Ludwig prided himself on not taking subsidies offered to silviculture operations elsewhere in Brazil by the Brazilian Institute for Forestry Development (IBDF), although the tax and import duty exemptions granted Jari were, in fact, important subsidies for the enterprise (Fearnside and Rankin, 1980). Jari's new management has entered the IBDF incentives program: IBDF underwrote 2500 ha of *Pinus caribaea* planted in 1986, 2500 ha of *Eucalyptus urophylla* planted in 1985, and 1000 ha of the latter species planted in 1984. The total of 6000 ha subsidized over the 1984-1986 period represents 16% of the area planted in those years. Jari is still exempt from Brazilian income tax and probably from duty on major imports such as the new power plant framework installed in 1986. Governmental subsidies still make Jari's economic status overly optimistic as an indication of how vastly larger plantations might fare elsewhere, given the finite nature of funds that the government can allocate to subsidies.

Although the Brazilian government continues to underwrite the enterprise through a variety of incentives and through the losses sustained by the state and mixed capital companies participating in the Jari consortium, the government has apparently not kept many of the promises that Jari staff say were made at the time of Ludwig's 1982 sale. (3)

Jari's Future Prospects

The economic future of Jari would be significantly brighter with completion of the hydroelectric dam planned for the Cachoeira de Santo Antonio on the Jari River. The planned dam would have 3 turbines, each with a generating capacity of 33 megawatts. Power generation would operate at full capacity (99 megawatts) only during the high water period. The site could generate a much higher peak power output, but only for a brief period each year. The dam will have a low storage capacity and at low water will only be able to operate with one turbine. Jari's wood-fueled thermoelectric power plant will continue to function when the dam is operational but will burn only bark and scrap. At present the thermoelectric plant consumes approximately 2000 m tons/day of chips (dry weight) to generate 55 megawatts of electricity. The city of Monte Dourado consumes only about 2.8 megawatts, but the pulp mill consumes all of the remainder. The dam would be an important item in reducing Jari's operating costs and in assuring power availability when Jari exhausts its ready supply of wood from native forest felled for the expanding plantations. The thermoelectric plant, perhaps fueled in the future from firewood plantations, will be necessary to allow the power of the widely fluctuating Jari River to be tapped. Jari has been collecting soil samples at the dam site for assessing moisture and physical properties. Still to be negotiated is the price that Jari will be charged for the electricity. Dam construction is expected to cost US$120 million *(Newsweek* 11 August 1986) to US$180 million *(Veja* 8 January 1986: 67). Agreement with the government still must be reached on the contributions to the dam's construction cost to be made by Jari and by ELETRONORTE (the government-owned power monopoly).

Antunes has repeatedly shown determination to make Jari into an economically viable undertaking. According to Jari staff, the remainder of the 22 firms in the consortium have been less willing to invest additional money in the venture. The five private banks participating in the consortium have been particularly uncooperative in contributing to further assessments and have insisted on receiving interest on previous contributions. Two government banks — Banco do Brasil and Banco Nacional de Desenvolvimento Econômico e Social (BNDES) — have contributed a large fraction of the enterprise's total capital (see Pinto, 1986: 206).

Antunes's personal determination is one of Jari's most valuable assets. Jari cannot count on the permanence of this source of emergency funds and high-level interest, since Antunes is now in his 80s. As was also the case during the tenure of the octogenarian D. K. Ludwig as Jari's first owner, the enterprise has repeatedly required committing funds and assuming risks beyond those that strict Baysean calculations of "expected monetary value" (EMV) might indicate as justified.

Despite the high turnover in employees, many of Jari's remaining staff are fiercely loyal to the enterprise and dedicated to making it succeed as an economic undertaking.

Antunes told the technical staff on 8 April 1986 that he wants to make Serra do Navio or Jari or both into showcase examples of research centers in the private sector, to demonstrate that the private sector can do research more efficiently than the government and that it can be done with a view to long-term improvements rather than merely for immediate profits. At the very end of Ludwig's tenure the research staff had been reduced to a single person. Jari now has a research staff of six in its forestry sector, including one resident EMBRAPA functionary and two EMBRAPA researchers released on leaves of absence to assume temporary contracts at Jari. A new research building has been constructed and a computer system is being installed. Research is an important prerequisite if the estate is to further diversify its plantings and improve its management practices.

Conclusions: Jari's Lessons for Carajás

The experiences of 19 years of large-scale silvicultural plantations at Jari are relevant to the prospects of even larger silvicultural plantations planned for charcoal production in the Grande Carajás area. Jari's plantations have proved to be far more costly and less productive than originally envisioned. Problems have included inappropriate soils for some of the species planted, intolerance of some species to the occasionally severe dry periods inherent in the variable climate that characterizes Amazônia, and a variety of pests and diseases. Despite these problems, Jari continues to pursue silviculture in the expectation that future increases in world pulp prices, combined with continued reduction of costs and risks in the production process, will make the operation profitable. However, neither Jari's continued dedication to silviculture nor its substantial achievements in eliminating operating losses can be interpreted as meaning that large scale silvicultural plantations are now an economically viable development mode in Amazônia. Jari's silviculture sector has been losing money despite the estate's widely publicized achievement of an overall operating profit: the losses from silviculture have been compensated by the profitable kaolin mine. The operating profit also does not include debt service. Even were these factors included, the low purchase price paid by the current owners relative to the investments needed to implant Jari means that profitability from the vantage of the present Jari consortium would be insufficient to make the estate a model for other silvicultural undertakings.

The Grande Carajás program's pig-iron scheme would require vast silvicultural plantations to supply charcoal. Sustainability of these plantations, as at Jari, will require a minimization of biological risks and a balance of inflows and outflows of ecosystem nutrients. The charcoal demands of 11 enterprises for which financial incentives had been approved by May 1986, including 7 pig-iron plants, have been estimated at 1.1 million metric tons annually (Brazil, Presidência da República, Programa Grande Carajás, CODEBAR and Ministério do Interior, SUDAM, 1986: 2). Information on charcoal demands and pig-iron mill construction plans described by Francisco Sales Batista Ferreira, head of the Grande Carajás Interministerial Program, allow calculation of silvicultural plantation requirements based on the yields at Jari (Table VIII). These calculations reveal that over 700,000 ha of *Eucalyptus* plantations would be needed, or an area almost 10 times that of the managed plantations at Jari.

Because of their vast area, the silviculture plantations necessary to supply the pig-iron plants of Carajás would face problems and uncertainties even greater than those at Jari. The magnitude of the investment required by such a scheme also indicates the likelihood that the 20 pig-iron plants for Carajás will use large amounts of wood from felling native forests for as long as these forests continue to exist in the area. Native forest felling does avoid, at least temporarily, the costs of planting and maintenance associated with silviculture. The pig-iron plants of Carajás are therefore likely to become major forces speeding the deforestation of Eastern Amazônia.

The difficulties of sustaining large-scale silvicultural operations in Amazônia illustrated by Jari apply not only to Carajás but to any project that calls for establishing vast expanses of tree plantations in the region. As the plans for Carajás show, Jari is not the last such project. The planners of Carajás and other projects should ponder well the lessons learned at Jari. [4]

NOTES

1. Wood shortage was not the reason for either the slowdown or the stoppage, according to the mill staff. Mill output had been falling because of the limited power output (down to 40 megawatts since November 1985, as compared to full capacity of 55 megawatts). The power plant returned to full capacity in late March 1986 after repairs to its supporting framework. The power plant was operating below capacity to avoid harmonic vibration from the turbine caused by the broken framework and because the absence of bedrock at the site had obliged the plant's builders to mount the plant on wooden posts that are subject to settling. A new framework for the plant was made in Japan and shipped to Jari.

2. Table VI assumes that all plantations older than the harvest age given in Table II have continued to grow at the same yearly rate, and that the contribution from native forest for species other than *E. deglupta* are half the percentage of the pulp mix as Jari uses for *E. deglupta*. It is assumed that *E. urograndis, E. camaldulensis, E. pellita,* and native and expermental plots all grow at the same rate as *E. urophylla*. Rotations equal to that of *E. urophyla* are assumed for these species, with the exception of the experimental plots, for which a rotation equal to that of *P. caribaea* is used.

3. In a speech to Jari's technical staff on 8 April 1986, Antunes said that the government has yet to regularize the estate's land titles, approve construction of the proposed hydroelectric dam on the Jari River, take over the schools at Monte Dourado, pave the airport runway, or maintain the city streets, airport and other municipal infrastructure. The government health department (SESP) has taken over the hospital, although Jari is obliged to contribute a supplement to the doctor's salaries in order to keep the facility operating.

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