THE NEW JARI: RISKS AND PROSPECTS OF A MAJOR AMAZONIAN DEVELOPMENT

PHILIP M. FEARNSIDE
and JUDY M. RANKIN

"Jari", the group of three enterprises[1] developed by shipping magnate D. K. Ludwig, is an estate in Brazil's State of Pará and Federal Territory of Amapá claiming 1,632,121 ha[2] of land straddling the Jari River, a northern tributary of the lower Amazon. Silviculture, pulp manufacture, rice growing, mining and logging are among Jari's main activites. The Jari project is currently at a major "crossroads" as final details are settled for the sale of this tremendous operation, with control passing to a consortium of 27 Brazilian firms led by mining entrepreneur Augusto Trajano de Azevedo Antunes (*Veja*, 16 de dezembro de 1981). Continuing heavy losses[3] have been a major factor in Ludwig's decision to sell the project, in which he had invested over US$ 1 billion, for the much lower figure of US$ 280 million (US$ 180 million in debts assumed + US$ 100 million payable over three years)[4].

Jari has often been suggested as a potential model for developments throughout the Amazon Basin. While many details of Jari's operations have changed since we addressed the question of Jari's applicability as a development model for the region (Fearnside and Rankin, 1980), the arguments advanced in that discussion remain valid, indicating that any suggestion to apply Jari as a model must be approached with extreme caution. The financial crisis at Jari leading up to Ludwig's decision to sell (Kinkead, 1981) has now focussed debate in Brazil in the risks and prospects of Jari itself.

One viewpoint expressed at recent international meetings (Russell, 1981; Alvim, 1981) is that Jari is itself "technically viable", even though political and institutional problems might have been rendering the Ludwig operation untenable. Such claims must be examined closely. The question of Jari's future course under new management requires examination in light of interdependent ecological, economic and social factors affecting contemporary developments in Amazonia. The present paper is an attempt to bring new data, garnered from recent site visits[5] and the growing number of scientific publications on research performed at Jari, to bear in the analysis of these factors.

Prospects of Jari's Operations

Silviculture, Timber and Pulp

Plantation silviculture, native timber extraction and pulp mill operation, are the principal activities at Jari in terms of capital invested, land, and employment. The controlling factor in virtually all aspects of the silviculture and pulp operations is, and must be, the continued supply of wood for pulping and power generation on a day-to-day basis.

Native timber, originally burned on the site, is now heavily utilized[6] as fuel to fire the boilers supplying power to the pulp mill, as a component of the pulp produced by the Kraft pulp mill on the site, and as construction materials. Plantation monocultures of three species supplant the native forest: *Gmelina arborea* has been planted commercially since 1969, *Pinus caribaea* var *hondurensis* since 1973, and *Eucalyptus deglupta* since 1979. The silvicultural plantations continue to be managed without artificial fertilizer inputs to balance nutrient losses due to the harvesting of native timber and the plantation species. Continued removal of nutrients from the system in the form of harvested biomass will eventually deplete stocks of available nutrients to the point where growth is reduced to uneconomic levels. Company foresters say that a slight decrease in growth rates has already been noted in the second cycle of *Gmelina*. The inevitability of a future added cost for fertilizer purchase and application, not currently being considered in silvicultural calculations, has yet to be faced by project managers.

Dr. Philip M. Fearnside, an ecologist, received his Ph. D. in Biological Sciences from the University of Michigan, Ann Arbor, Michigan U.S.A. in 1978. He is especially interested in the estimation of carrying capacity for human agricultural populations. His work has been directed at this problem in the Brazilan Amazon since 1973. He is presently a Research Professor at the Instituto Nacional de Pesquisas da Amazônia (INPA), Caixa Postal 478, 69.000 Manaus Amazonas, Brasil.

Dr. Judy M. Rankin, an ecologist, received her Ph.D. in Biological Sciences from the University of Michigan, Ann Arbor, Michigan, U.S.A. in 1978. Her main interests lie in the dynamics of tropical rain forest communities. She is especially concerned with the demography of tropical rain forest trees and natural regeneration, a process holding great potential for sustained yield forestry under Amazonian conditions. She is presently an Associate Research Professor at the Instituto Nacional de Pesquisas da Amazônia (INPA), Caixa Postal 478, 69.000 Manaus, Amazonas, Brasil.

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A predictable, sustained supply of wood is essential to the pulp mill's functioning and to Jari's existence. The cost of down time at the pulp mill is US$ 14,000/hour, meaning that all other operations at the estate must be coordinated to guarantee that the mill never has to stop for lack of wood either for pulp or fuel. This overriding priority was the motivating force for the testing and eventual inclusion of native tree species in *Gmelina* pulp when early *Gmelina* production was found to be insufficient to meet pulp mill demands. The urgency of feeding the mill also led, in 1981, to some of the *Pinus caribaea* plantations with spacings intended for 16-year saw log rotations being cut for pulpwood, while others were converted to faster growing *Eucalyptus deglupta* (C. E. Russell, personal communication, October 1981).

Plantations can be of three types: pulpwood, solid wood, and fuelwood. Costs of producing seedlings and establishing plantations are similar for the three types, but the values of the three products are very different, solid wood being much more valuable than pulpwood, which is more valuable than fuelwood. In the U.S., wood in the form of lumber has a value 3.6 times that of wood in the form of fuel (Pimentel *et al.*, 1981: 334). The need to keep the mill supplied at all times means that opportunities to produce more valuable products must be sacrificed to plant pulpwood, and in the future firewood, plantations. Losses of potential income from this situation will become more acute when native forest is exhausted.

It is then critical to know how much plantation, at present levels of productivity, is needed to supply the pulp mill, and the prospects for the sustainability of such productivity. Plantation productivity below expectations has been one of Jari's most persistent problems: yields have been, on average, approximately half those anticipated by Ludwig at the outset of the project.[7] Finally, information on plantation requirements must be translated into pulp production costs and evaluated in terms of world markets for the pulp produced and for the inputs required.

A rough idea of the costs of supplying soil nutrients removed in the plantations can be gained from the composition of the biomass removed in the case of *Gmelina* (Table I). The nutrients in the *Gmelina* bark greatly increase the total drain from harvesting, as concentrations are substantially higher in bark than wood for many elements.

The amount of fertilizer needed to achieve continued production of *Gmelina* at present levels would have to be greater than the amounts absorbed by the planted trees, since much of what is applied is lost to leaching and runoff, or, in the case of phosphorus, to fixation into unusable compounds in the soil. The amounts lost vary greatly, depending on soil, rainfall, type of fertilizer, and mode and timing of application. The recovery efficiencies used in Table I are rules of thumb for crops in general. The highly leached soils and high rainfall characteristic of the Amazon could mean that recovery would be lower at Jari. Phosphorus fixation rates (in 6 hours at 100 ppm P) range from 26.8 to 51.6% in representative soils of the Brazilian Amazon (Fassbender, 1969). These rates are not high by the standards of many tropical latosols, but more phosphorus is lost to fixation at low (and more probable) fertilizer application rates. In *terra roxa* (ALFISOL) in Altamira, Pará, the same soil type as Jari's best *Gmelina*-growing soils, up to 83% of P applied is fixed in 7 days at low (53 ppm P) application rates (Dynia *et al.*, 1977).

To the cost of purchasing fertilizers one must add the cost of application. Information is not available on the amount of labor required to fertilize *Gmelina* plantations, but an idea can be gained from labor requirements for cacao plantation fertilization. INCRA (Brazil, Ministério da Agricultura, INCRA, 1972: 168) uses a figure of 2 man-days/ha/year to fertilize cacao on the Transamazon Highway planted at the same 3 x 3 m density used (after thinning) for Jari's *Gmelina*. A portion of the cost of supplying this additional labor can be calculated from the workers' pay.[8] Labor for fertilizing would add US$ 8.48 /ha/year to the costs, raising the total to US$ 142.47/ha/year.

In addition, if plantation wood were to fuel the boilers of the mill's power plant on a sustainable basis, fertilizer for the fuelwood plantations would have to be included in the calculation. Of the 55 megawatt output of the power plant, 76.5% is consumed directly by the pulp mill, the balance being used for the sawmill (5.5%), kaolin mill (4.6%), and the towns of Monguba and Monte Dourado (4.6%). At present, the boilers consume 1500 kg wet weight/day of fuelwood chips to supply 80% of the power output, the other 20% coming from fuel oil (Woessner, 1980a).[9] Assuming that oil consumption cannot be lowered below 20%, the amount of wood needed for fuel would be a 37.5% addition to the pulpwood need, or a 28.7% addition for only the portion of the power output used by the mill itself.

The costs of fertilization per hectare must be converted to costs per metric ton of pulp produced, since this is the unit in which the added expense of fuelwood plantations, among other factors, becomes apparent, and is also the unit closest to the market prices ultimately determining the profitability of fertilizing to achieve a sustainable nutrient balance. The US$ 142,47/ha/year cost of purchasing and applying fertilizers to pulp plantations would correspond to US$ 9.87/metric ton dry wood produced at the 38 m^3/ha/year maximum yield level (Woessner, 1980a) and the 0.38 g/cm^3 wood density (Woessner, 1980b). The cost would be US$ 3.79/metric ton of wet wood chips, since *Gmelina*, green wood weight is approximately 260% of dry wood weight, according to company technical staff. The cost of fertilizing the pulpwood plantations per metric ton of pulp produced would be US$ 21.08, using a conversion rate of 0.18 metric tons of pulp/metric ton of wet wood chips (calculated from Woessner, 1980a, indicating that present daily mill output of 720 metric tons pulp is produced from pulping 4000 metric tons/day of (wet) chips). Adding the 28.7% extra plantation area needed for producing fuelwood on a sustainable basis for power used directly by the mill, the cost per metric ton of pulp increases to US$ 27.13.

The actual cost would be higher than the figure computed above, since many other costs have not been included in the calculation, such as transporting the fertilizer, planning, supervising, administering, and monitoring its application, and supplying nutri-

> In silvicultural operations generally, many potential management remedies are not solvable at acceptable costs through traditional agricultural remedies such as chemical treatments.

ents other than the four considered here. The *Gmelina* wood and bark removed annually would contain 44.64 kg/ha magnesium, 5.13 kg/ha sodium, 721.1 g/ha iron, 270.7 g/ha manganese, 737.7 g/ha zinc, and 43.3 g/ha copper.

At present price levels, the US$ 27.13/metric ton cost increase would represent 6% of the US$ 476.40 average price received for Jari's pulp output, but would represent a substantially greater fraction of any profits. At the 750 metric ton/day plant capacity, the cost would represent US$ 7.3 million/year in addition to Jari's current loss rate without the expense of fertilization. The 38 m³/ha/year maximum yield for *Gmelina* used in these calculations is not attained in much of Jari's plantation area, and any lower yield level would imply a substantial increase in cost/metric ton of pulp. This is an extremely important point, since the less-than-ideal nature of most of Jari's *Gmelina* soils translates into millions of dollars of additional losses. Every 5 m³/ha/year drop in *Gmelina* yields would raise costs by US$ 1 million/year for fertilizer alone, and many times this much for the other expenses of plantation establishment and maintenance. Jari officials say poor soils yield only 12 m³/ha/year of *Gmelina,* but information on the areas of *Gmelina* planted on soils of each site index [10] is unavailable.

The number of rotations of *Gmelina* during which soil nutrients can be removed without replacement is undoubtedly quite small. Of particular interest is the case of phosphorus, often a limiting factor in Amazonian agriculture. Using a soil bulk density of 1.65 (see Table I, note 5), samples of the top 20 cm of soils under *Gmelina* (Table I, note 2) indicate an average total phosphorus stock of only 24.2 kg/ha in this layer. Company soil profiles to 60 cm depth indicate the usual pattern in Amazonian soils of most phosphorus and other nutrients being concentrated in the upper layers of the soil. Phosphorus removed in *Gmelina* wood and bark alone totals 4.0 kg/ha/year (see Table I).

Initially the plantations can be expected to have a supplementary supply of soil nutrients from the decomposition of the root mat of the former rain forest, a factor found to be a significant nutrient source in the first few years following clearing in the San Carlos de Rio Negro region of Venezuela (Herrera *et al.,* 1978: 227). The remains of the underground biomass stores of the former rain forest can be expected to disappear rapidly. Similar inputs from decomposition of plantation trees (and the leaves and branches left in the field)

TABLE I:

REPLACEMENT COSTS OF NUTRIENTS EXPORTED IN *GMELINA* BIOMASS

Item	Units	N	P	K	Ca	Total
Nutrient Content						
Gmelina wood	% dry weight (1)	0.13	0.02	0.23	0.15	
Gmelina bark	% dry weight (1)	0.78	0.04	0.44	1.35	
Eroded soil (2)	ppm	1720	140.28	14.50	7.33	
Rainwater (3)	ppm	<0.052	<0.011	<0.10	<0.10	
Nutrient Removal						
Gmelina wood	kg/ha/year (4)	18.8	2.9	33.2	21.7	
Gmelina bark	kg/ha/year (4)	20.7	1.1	11.7	35.8	
Erosion (5)	kg/ha/year	47.3	0.2	0.4	3.6	
TOTAL REMOVED	kg/ha/year	86.8	4.2	45.3	61.1	
Nutrient Supply						
Rainfall (6)	kg/ha/year	<1.21	<0.26	<2.34	<2.34	
Net Nutrient Loss	kg of element/ ha/yer	85.6	3.9	43.0	58.8	
Fertilizer Recovery (7)	%	55.5	15	55	(100) (8)	
Fertilizer Need	kg of element/ ha/yer	155.6	26.0	78.2	58.8	
Fertilizer Price (9)	US$/kg of element	0.329	1.724	0.427	0.078	
Fertilizer Cost	US$/ha/year	51.19	44.82	33.39	4.59	133.99

(1) Plant analyses done for Jari by North Carolina Department of Agriculture. Methods: micro Kjeldahl for N, photocolorimeter for P, flame photometer for K and Ca.

(2) Mean of 6 samples collected by the authors in *Gmelina* of various ages at Jari. Samples are composists of 15 cores each, 0-20 cm in depth. Analyzed by EMBRAPA-CPATU, Belém, methods (Guimarães *et al.,* 1970) same as (1).

(3) Rain water data courtesy of W. Franken of INPA (personal communication, 1982). They represent means of weekly samples in the period 23/01/79-23/02/81 in INPA's model hydrographic basin" at km 14 of the ZF-2 Highway, near Manaus. Similar values have also been reported by Sioli (1969) for the Rio Negro area, and by W. Franken (personal communication, 1982) for the Ducke Reserve near Manaus. No data are available for the Jari area itself.

(4) Wood densities at 17 months range from 0.29 to 0.38 g dry weight/cm³ green volume (=380 kg/m³) (Woessner, 1980b). The company's selection effort tries to maximize density, and the 0.38 g/cm³ value was used. According to company technical staff, 15-16% of wet weight of logs is bark; the midpoint, 15.5%, is used here, corresponding to 18.3% of the wet wood weight. The 38 m³/ha/year maximum growth attained for green inside bark yield (Woessner, 1980a) would result in an average of 14,440 kg dry weight/ha of wood and 2,649 kg/ha of bark removed annually, assuming bark density and water content same as wood.

(5) Erosion under *Gmelina* assumed equal to that found under young cacao on the Transamazon Highway near Altamira, Pará (Fearnside, 1980) for the first year, and zero for the remainder of the six-year rotations. The Altamira data is for 3 arrays of 15 measurement stakes each in areas with slopes of 2%, 17%, and 35%. Lowering of the soil surface includes soil compaction, as well as erosion. Mean change 10.0 mm during the 1975 rainy season observation period (SD = 8.3, N = 40 usable stakes). Annual rainfall in Altamira is 1697 mm (Falesi, 1972: 11), or 27% less than at Jari. Soil bulk density used in calculation is 1.65 g/cm³, the midpoint of the 1.6-1.7 g/cm³ range for control plots in Jari's soil compaction experiments in red-yellow podzolic soil, clay phase (UTLISOL).

(6) Calculated using 1968-79 average annual rainfall at Monte Dourado of 2335.1 mm (SD = 249.6, N = 12).

(7) Midpoints of fertilizer recovery of crops in general: 50-60% for N, 5-25% for P, and 40-70% for K (Cox and Atkins, 1979: 368).

(8) Calcium assumed 100% recovered: optimistic since Jari soil analyses (plot 881, block 76-1) show Ca++ falling from 36.0 ppm after burning to 8.0 ppm in the first year (a 77.8% loss).

(9) July 1979 Manaus prices calculated from Arkcoll (1979). These values can be expected to change radically with future fertilizer price increases as global petroleum and mineable nutrient stocks dwindle.

would not solve the problem, since the nutrients contained in these plant parts are needed to remake the same plant parts in each successive plantation cycle. It must be remembered that the plantation trees are not capable of extrancing all of the nutrients present in the soil, many nutrient forms being unavailable to the plants, in addition to the difficulty of capturing all of the stocks of those nutrients which are in available forms.

Data available on soil nutrient concentration changes in the plantations to date are not sufficient to identify or forecast nutrient depletion rates. Through 1980 Jari maintained 22 observation plots, with periodic analyses of soil pH, organic matter, available phosphorus, potassium, calcium, magnesium, sum of exchangeable bases $(Ca^{++} + Mg^{++} + Na^{+} + K^{+})$ and cation exchange capacity (exchangeable bases $+ H^{+} + Al^{+++}$). Soil analyses were done before felling the virgin forest, after clearing, after burning, and in subsequent years. Unfortunately, data are only available for the first three years under plantations, as the oldest plots are now six years old and the company switched from annual analyses to a scheme of analyses every three years prior to deactivation of this and most other research activities as a result of the financial crisis of 1981. As is usual in other types of agriculture in the region involving burning the forest (Fearnside, 1978), the results show sharp increases as a result of burning for pH, phosphorus, potassium, calcium, magnesium, exchangeable bases, and cation exchange capacity, and a decrease in toxic aluminum. Organic matter also increased somewhat with burning. In the year following the burn the levels of these soil quality indicators quickly return towards their pre-burn levels, some (especially organic matter) falling below the virgin forest levels. Most elements, including phosphorus and calcium, stop the abrupt decline from their post-burning peaks, to remain more or less constant through the second and third years of observation. Not enough time has elapsed to evaluate how these nutrients will change in future years, especially after such events as the end of decomposition of the forest root mat, diminished residual effects from burning, and the harvesting phase of future rotations.

TABLE II:

PULP MILL LIQUID EFFLUENT CONTENT(1)

Item	Jari River at Monte Dourado above mills, mine and towns (ppm)	Jari River at Monduga immediately above pulp mill (ppm)	Pulp mill effluent in outlet canal (ppm)	Added concentration from pulp mill in effluent (ppm)	Annual Loss from pulp mill (metric tons) (2)
NH_4^+	0.25	0.30	3.35	2.36 (N)	80.3 (N)
NO_3^-	<0.005	0.10	0.06		
SO_4^{2-}	<1.00	<1.00	<1.00	0 (S)	0 (S)
P	<0.10	<0.10	0.75	0.65	22.1
Cl-	2.50	5.00	312.50	307.50	10,462.5
Ag	<0.05	<0.05	<0.05	0	0
Al	<0.20	<0.20	8.86	8.66	294.7
B	0.30	<0.10	<0.10	0	0
Ba	0.29	<0.10	0.14	0.04	1.4
Ca	9.87	1.92	68.46	66.54	2,264.0
Cd	<0.02	<0.02	<0.02	0	0
Cr	<0.02	<0.02	<0.02	0	0
Cu	<0.02	<0.02	<0.02	0	0
Fe	<0.10	0.17	1.25	1.08	36.7
K	12.00	5.00	116.25	111.25	3,785,2
Mg	1.26	0.93	5.39	4.46	151.7
Mn	<0.01	<0.01	0.10	-0.09	-3.1
Na	8.12	2.82	205.70	202.88	6,902.9
Pb	<0.05	<0.05	<0.05	0	0
Si	29.81	5.80	15.06	9.26	315.1
Zn	<0.01	<0.01	<0.01	0	0
Ni	<0.02	<0.02	<0.02	0	0

(1) Samples taken by the authors, analyzed by CENA.

(2) Discharge is 1.1 m^3/second, 358 days/year. Density assumed of 1 gm/cm^3 for effluent water.

One possibility for reducing the cost of obtaining fertilizers would be the use of nutrients contained in the pulp mill's effluent (Table II). The value of the N, P, K, and Ca in the liquid effluent come to US$ 1.9 million /year, using the prices of Table I. Additionally, a considerable quantity of solid waste precipitates out in the holding ponds before the effluent reaches its release point. The nutrient-rich bark removed in the debarkers prior to chipping the pulpwood might also be a valuable nutrient source: bark accounts for 12.3% of the monetary value of the four nutrients considered in Table I. If recycled, the bark's share of these nutrients would be worth US$ 0.6 million/year at present *Gmelina* harvest rates. Clearly the costs of preparing and transporting usable portions of the mill's waste would be significant, and would have to be carefully calculated before implementing any full scale nutrient recycling scheme. As the necessity of supplying nutrients to the plantations makes itself apparent, some of these nutrients may prove worthwhile returning from the mill site to the silvicultural stands.

Long term viability of fertilizing Jari's plantations, as in many of the forms of high input agriculture around the world, is clouded by the diminishing global store of inexpensive nutrients. Projections of world trends indicate both potash and phosphate rock being exhausted by the year 2061 (United States, Council on Environmental Quality and Department of State, 1980).[11] Utilization of low grade deposits after this date would result in dramatic price increases, as well as requiring presently unachieved technological breakthroughs.

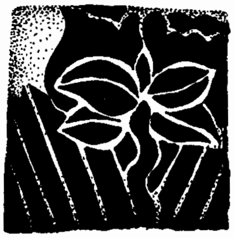
In addition to the cost of suppliyng nutrients to the plantations, with or without better recycling in the system, plantation area will have to increase to compensate for wood presently derived from native forest. Establishing, maintaining, and harvesting the 37.5% additional area for firewood will make supplying energy a major figure in Jari's books at some future date, although the cost would be reduced if the contemplated hydroelectric dam at Cachoeira de Santo Antonio is built.

The 15% of the present *Gmelina*-based pulp mix derived from native forest trees (Woessner, 1980a) will also have to be supplied from plantations, raising costs accordingly.

Prospects for Jari's silviculture and pulp operation depend, in addition to establishing an equilibrium between nutrient inflows and outflows in the system, on low risks of major yield setbacks from pests, diseases, or other agronomic problems. Decline in soil nutrient levels can be expected to act synergistically with other factors to further jeopardize silvicultural yields. Less than optimal soil fertility for tree growth, such as early *Gmelina* sites located on inappropriate soil types, increases the susceptibility of plantations to insect pests (Johnson, 1977). Site deterioration through soil compaction and other processes expected to increase with future rotations will further exacerbate this problem.

The probability of significant losses to insect and disease outbreak can be expected to increase with increasing area of monocultures planted,[12] and with the passage of time during which pests and disease organisms not yet present can become established.[13] Defoliation by pests can reduce plantation tree growth by varying amounts (Ribeiro and Woessner, 1980), adding to the plantation area that would be needed to meet the pulp mill's demand for wood.

In silvicultural operations generally, many potential management problems are not solvable at acceptable costs through traditional agri-



cultural remedies such as chemical treatments. If a major disease problem arises, for example, the only option usually open is to switch to a new species unaffected by the problem. Preparing the operation to counter such problems is difficult and costly, but essential. Jari would be wise to adopt as a goal the ability to sustain the loss of one of its plantation species.

Finding alternative species is not an easy process. The *Eucalyptus deglupta* being planted on a commercial scale since 1979 had performed well in young trial plots on some sites prior to initiation of commercial planting, but only a few areas could be tested prior to adoption. *E. deglupta* is a species known for more varied growth than most, with isolated trees or small plots commonly doing much better than large commercial stands (R. G. Lowe, personal communication, 1980). *Anthrocephalus chinensis,* a species which has given excellent results in trials on some Jari sites, has not been planted commercially because it demands good soil, has narrower requirements for amount and timing of water than other species, and is susceptible to a disease, not yet arrived at Jari, which has attacked plantations in Central America (C. Briscoe, personal communication, 1980, see Gibson and Nylund, 1976).

Pulpwood plantations, as in many forms of agriculture, are sustained through a continued struggle of the humans managing the system with biological, silvicultural, and technical problems. The relatively long cycle of the crops, and the large investments involved, make it especially difficult to steer a successful course where problems must be anticipated and corrective action taken several years before yield declines become economically significant. To a certain extent the sustainability of the system depends on high quality research and monitoring efforts.

The relative prices of pulp as compared with needed inputs will be crucial in determining whether steps are taken by management to increase the likelihood of long term production. Pulp prices can be expected to rise as world consumption of white chemical pulps continues to increase from 43.8 million metric tons per year in the 1972-73 period to a projected 67.1 million metric tons per year in 1990 (United Nations, F.A.O., 1977: 144). Whether rising prices of inputs will cancel these gains is unknown: commodity prices are, unfortunately, more responsive to supply and demand at any given time than to the cost of investments needed to sustain production at some future date.

Political and bureaucratic decisions affecting the silvicultural operation may have at least as much impact on its ultimate sustainability as the many biological and agronomic threats to continued production. Regulations regarding marketing and pricing are particularly important,[14] among many other factors.

Irrigated Rice

The irrigated rice project in diked *várzea* (floodplain) at São Raimundo has recently undergone setbacks, both agronomic and economic, leading to management changes and close scrutiny of the project. One major cause of worry was a sharp fall in rice yields in 1979 to about 7 metric tons/ha/year from slighty over 8 metric tons/ha/year in the previous year. Various contributing causes have been identified, and some have been remedied through management changes. One reason for the decline was iron toxicity, evinced by accumulation of brown sludge on the rice roots. Although the area's soils are prone to this problem, iron toxicity can be minimized through careful water management in the paddies. A delicate balance exists between excessive flooding, leading to iron toxicity, and dryness, leading to aluminum toxicity. A preflood helps raise pH levels and reduce iron toxicity.

Increased insect attacks are believed by the technical staff to be a major factor affecting rice yidds. Army worms *(Spodoptera frugiperda)* are a particularly persistent problem, which can quickly inflict severe losses if timely and effective controls are not taken each time populations begin to increase. The army worm problem, like the toxicity problems, is linked to water management: flooding the paddies when the worms are young being an important weapon in the battle to control these pests (see Grist, 1975: 320).

Stink bugs *(Oebalus poecilus)* have also been a problem believed to contribute to yield declines. Attacks of these insects on rice roots have a synergistic effect with iron toxicity contributing to reduced absorption of nutrients by the rice plant. The plants respond to roots being punctured by stink bugs by replacing them with additional roots. Foliar symptoms of nutrient deficiencies can easily lead to the conclusion that increased fertilizer applications are needed, a response the current technical staff likens to treating a human patient suffering from intestinal parasites by applying blood transfusions or additional food. Increased attention to insect problems may reduce the cost and increase the effectiveness of future responses to these symptoms.

Nematodes are an additional problem found by the current team of technical staff, which began work at the IRI Research Institute station associated with the rice project in the latter part of 1980. The problem's severity and the possibility of control are still under investigation. Aphids (Aphididae) in the rice roots and mites (Acari), are two additional problems discovered by the present research team.

Rice diseases present include rice blast *(Piricularia oryzae),* to which the IR-22 variety now being phased out is very susceptible (but which did not inflict economically significant losses during the time that IR-22 served as Jari's mainstay). Leaf scald *(Rhynchoporium oryzae)* has been the most damaging disease for both IR-22 and J-226. J-226 seed is being propagated as a promising replacement for both IR-22 and the J-229 progressively supplanting IR-22 since 1979. Brown leaf spot *(Helminthosporium oryzae)* is also present, as well as a little false smut *(Ustilagenoides virens).* Although diseases represent a constant worry to rice growers, Jari's rice has not suffered unduly from them so far. "Hoja blanca" virus, a major problem in Venezuela, has still not arrived at Jari. The most effective response to disease problems is generally a switch to more resistant varieties, chemical treatments representing only a temporary measure. The greatest problem is ability to produce sufficient seed fast enough to effect a variety change when and outbreak occurs (given that a resistant variety is available in the pool of strains undergoing testing at the site). Sufficient seed was not available to complete the switch from IR-22 to J-229 two years after the change began, and J-229 is now already slated for replacement as soon as enough J-226 seed is available.

Weeds are a continual worry in the Jari rice project, as in irrigated rice everywhere. Barnyard grass *(Echinochloa crusgalli)* is present at low levels throughout the rice area, although it has not exploded to inflict the severe losses it is capable of causing. Wild red rice *(Oryza rufipogon)* is now present at Jari's São Raimundo rice project in low levels. Wild red rice is a major problem in many parts of the world because it is difficult to distinguish from domestic rice *(O. sativa),* many seeds fall from the panicles before harvest allowing it to reseed in the paddies, and any grains harvested shatter when milled, thus lowering product quality. The most effective way to control these and most other weeds is to pre-flood the fields to germinate the weeds, followed by draining and multiple herbicide sprayings prior to flooding and planting. These time-consuming and expensive procedures are so far only used for the seed production beds. In production fields weed control is presently limited to one spraying before planting (either Dalapon of Gramoxone), followed by spraying with Stam (Propanil) when the rice is growing. One marantaceous weed *(Thalia geniculata)* has not been sucessfully controlled with these procedures, but the problem has not grown to economically damaging proportions. Other weeds include an unidentified *Phaseolus* species, and another wild rice species *(Oryza alta).* Two major graminaceous weeds in Surinam (Barett, nd. (1975)) not yet arrived at Jari (R. Cheaney, personal communication, 1980) are *Leptochloa scabea* and *Ischaemum rugosum.* The latter is considered the "most dangerous grass in Surinam" (Doeven and Peorink, 1955, cited by Grist, 1975: 280).

Political and bureaucratic decisions affecting the sylvicultural operation may have at least as much impact on its ultimate sustainability as the many biological and agronomic threats to continued production.

A number of remedies are underway for the various agronomic problems and the decline in rice yields may not continue if these are effective. A major effort is improvement of the physical structure of fields and dikes to allow more finely tuned and rapid responses to water management problems. Fields are being regraded at considerable expense. Slight depressions and "high spots" in the present fields have been a constant headache hampering uniform flooding or drying of fields to control insects, weeds or other problems. Army worms, for example, preferentially attack high spots. Another engineering change began in 1980: construction of an additional canal through the middle of each large field, allowing independent filling of each of the paddies into which the large fields are divided. The new canals reduce the time required to fill a paddy from eight days to 36 hours. The new canals in presently existing rice production fields will be complete by the end of 1983, if the construction schedule is followed.

Beginning in 1980, rice crops are planted on a rolling basis rather than in two distinctly separate and more synchronized cropping periods. The number of crops obtained from any given paddy is still limited to two, as the remaining time is insufficient for a full third crop. In the future the J-226 variety may allow about 30% of a full crop's yield to be harvested from resprouts as a stubble crop during this time slot, but this possibility is still, in the testing phase. Rotation crops other than rice are also being tested, including sweet potatoes *(Ipomoea batatas),* maize *(Zea mays),* sunflowers *(Helianthus annus),* sorghum *(Sorghum vulgare),* cow-peas *(Vigna sinensis),* winged beans *(Psophocarpus tetragonolobus),* soya beans *(Glycine max),* peanuts *(Arachis hypogaea),* and an unidentified local legume green manure crop. Taro *(Colocasia esculenta)* is being tested as a potential alcohol crop, and a native papyrus *(Cyperus* spp.) may be tested as a potential pulp source. Rotation crops could help reduce pest problems, as well as fertilizer costs in the case of green manure crops.

The search continues for rice varieties more tolerant of suboptimal management, and for varieties with greater tolerance for iron toxicity. Variety screening continues, as well as research on possible rice management changes. Research on annual crops on *terra firme* (unflooded uplands) at São Raimundo was discontinued in 1979.

Better insect population monitoring methods have been instituted in the irrigated rice fields (sweep net transects rather than 1 m^2 quadrats), and spraying programs have been adapted to try and control more insect outbreaks before they become severe. Sprayings have increased from only 2/crop to 5-6/crop to achieve better control (note: in part to compensate for aging stocks of pesticides), although army worms are not yet resistant to the main foliar insecticide used, Folidol (methyl-parathion). The coordination of applications of various agricultural chemicals so that certain chemicals don't neutralize the effectiveness of other chemicals is essential. The systemic insecticide Furadan (carbofuran), for example, must be applied before the herbicide Stam (propanil), whereas Folidol (methyl-parathion) must be applied 6-7 days after Stam (propanil). Human errors on these and other details have caused production losses.

The dependence of the mechanized agriculture used in the rice operation on fossil fuels continues to be a potential long term problem. Cost and availability of fuel will be important factors in the future. Temporary shortages of natural gas have required shutting down the rice dryers at least once, although the diesel pumps lifting water in and out of the polder surrounding the rice fields have not been affected so far. Posts have been installed for future electrification of the diesel pumps. Electricity would be supplied from a generator burning crude oil, unless Jari's hydroelectric dam is authorized and built.

The future prospects of the rice project depend on many factors. Biological problems can be expected to become more severe as additional weeds, pests, and diseases arrive in this new rice producing area, and as pest populations develop resistance to chemical treatments being applied (Fearnside and Rankin, 1980). At the same time management practices can be expected to improve, as more is learned about how to grow rice in this new area, and as new varieties, equipment and other improvements in physical parts of the agroecosystem become available. Costs related to the project's isolated setting and minimal infraestructure (no road link yet exists) can be expected to decrease, as can costs from the large staff required for engineering works in present fields and, eventually, for completion of the project's now stalled expansion phase. Economies of scale would also be expected to reduce per hectare costs more as the project expands from its present 3062 ha size to its projected 14,165 ha.

To a great extent the prospects for sustainability and profitability of the rice operation depend on the skill and dedication of the people who run it. Agriculture of this type is a continual balance between the ability of the humans involved and the ever-changing biological and other problems threatening production. The cost of a single mistake can often be an entire crop.

In addition to agronomic an human factors, the rice operation's future depends heavily on political and economic decisions beyond the company's control. Export restrictions and price controls are chief among these. These restrictions are presently seriously affecting the project, probably representing a greater source of concern to the company than the dip in rice yields in recent years. Only one rice crop was ever exported, the first crop of 1978, sold to Italy. Since that time the company has been required to sell all production on the Brazilian internal market at controlled prices well below those for rice of this quality on international commodity exchanges.

The performance of the rice project in recent years has not been encouraging. Ludwig tried unsuccessfully to sell a controlling 50% interest in the project to Atlantic Richfield Corporation (ARCO), but after an 18-month trial period, ARCO exercised its option to cancel the sale in June 1981. Paralyzing expansion plans and great reduction in personnel had failed to reverse the drain on cash resources. The rice project's 1980 cash flow was estimated at approximately US$ 10 million (Kinkead, 1981).

Water Buffalo

Jari's herd of 5800 water buffalo in unaltered *várzea* (floodplain) grasslands helps reduce the project's costs for dairy products and meat. Jari personnel are pleased with this animal's adaptation to native Amazon floodplain, as has been the experience of private ranchers and government experimenters in various parts of the Amazonas and Solimões Rivers. In the case of the portion of Jari's herd along the Araiôlos River below the rice project, it would be well to monitor the milk and cheese produced for pesticide residues. Long term residents in the Araiôlos River area remark on changes in river water quality and fish catch since the implantation of the rice operation. Chemicals used in the rice project include the pesticides Folidol (methyl-parathion), SEVIN (carbaryl), Toxaphene (chlorinated camphene), and Furadan (carbofuran). The principal herbicides used in the fields are STAM (propanil), Dalapon, and Gramoxone; lesser quantities of Anthrophene are also used on leeves.

Pasture with Pine

A herd of 6300 zebu-herford hybrid beef cattle[15] is apparently doing well in pastures interplanted with *Pinus caribaea* three years of age, without doing significant harm to the pine seedlings. Initial use of guinea grass *(colonião: Panicum maximum)* has been discontinued in favor of the more covering and resistant creeping signal grass *(Quicuiu da Amazônia: Brachiaria humidicola)*, a grass species currently being promoted for pastures throughout the Amazon *terra firme* (uplands) by the Brazilian government based on EMBRAPA experiments[16].

Kaolin Mine

Jari's open-pit kaolin (china clay) mine presently represents a small area of forest destruction when compared with other land uses, a contrast which is even greater if the difference in value of the products is considered.

> Foliar symptons of nutrient deficiencies can easily lead to the conclusion that increased fertilizer applications are needed, a response the current technical staff likens to treating a human patient suffereng from intestinal parasites by applying blood transfusions or additional food.

Jari officials say the size of the deposit could supply the mining operation at the 1980 extraction rate for 250 years, although the extraction rate is expected to be increased in 1982 according to the company[17]. The small disturbance of the current operation could therefore be expected to increase tremendously as extraction proceeds through the coming two centuries. The problem of reclaiming these much larger areas will therefore eventually have to be faced.

Environmental Risks

Silviculture

The size at which replacement of natural forest with plantations would provoke significant wider environmental effects is unknown, but probably large in comparison with Jari itself. Reduced rainfall is the macroecological effect most closely tied to deforestation in general (Salati *et al.*, 1978; Fearnside, 1979). Increased severity of the dry season is a greater reason for preoccupation about deforestation than are decreases in annual rainfall totals. Jari's silvicultural plantations could be expected to have less impact than the Amazon region's fast-growing areas of cattle pasture, but would have more than land uses which maintain intact rain forest canopy cover. Transpiration is largely a function of leaf area, implying that the transpiration potential of the plantations is less than that of rain forest. Evapotranspiration, mostly transpiration, has been found to account for approximately half of the water vapor generating rainfall between Belém and Manaus (Villa Nova *et al.*, 1976; Salati *et al.*, 1978). Large-scale modification in the evapotranspiration potential could therefore be expected to cause similar changes in rainfall for the region. Precipitation records for rain gauges maintained by Jari at Monte Dourado since 1968, and at other locations in the silvicultural area since 1970, 1971, 1974, and 1975, do not reveal any significant trends in total rainfall, or in such dry season severity indicators as number of days of rain in each of the dry season months, minimum number of days of rain in any month, and minimum rainfall in any month. The time sequence is, however, too short to allow conclusions.

Risk of any eventual climatic effect is minimized by the large areas which must be converted before any measureable change is provoked. Jari's area is small in comparison with the 3.5 million ha of cattle pastures estimated to exist in Brazil's Legal Amazon by 1978 (Serrão *et al.*, 1979) and the rapid increases in cleared areas since that time (Fearnside, 1982). Beyond Jari itself, probable limitations on the spread of large silvicultural operations in Amazonia would include how much of the Amazon is suitable for this kind of plantation, and how much plantation area would be needed to supply projected market demands (not to imply that all market demand should be supplied or that all suitable areas should be used). It is well to remember that macroecological effects are generally cumulative in nature, being the combined result of many smaller strains on the system, none of which is sufficient in itself to provoke the change.

Pulp Mill

Water pollution from pulp mill is treated by filtering solid sludge, followed by holding the effluent for 16 days in a series of 1 m deep ponds where bacteria act to degrade organic materials. The 159 ha of ponds include capacity for emergency drainage of digestors, not included in original plans. The relatively inexpensive ponds, constructed with simple earth dikes, allow much cheaper pollution treatment than would be possible in temperate zones where covered concrete tanks are needed to maintain water at the required 30°C temperature. In late 1980, Brazil's Special Secretariat of the Environment (SEMA) took the additional precaution of requiring a further enlargement of the pond area, since the ponds were nearly full. The enlarged ponds are under construction (P. Nogueira Neto, personal communication, Feb. 1981).

Most of Jari's other operations, such as timber extraction for solid wood, kaolin mining, and irrigated rice, involve the destruction of natural habitats.

Effluent, a brown liquid with a distinctive odor (Table II), is released into the Jari River at the river bottom (about 18 m deep). An 80 cm tide at the mill site in Monduga causes water to flow upstream each day as the tide comes in, restricting effluent release times to the hours when water is moving at its maximum rate downstream. The 1.1 m^3/second average discharge is therefore concentrated into much larger effluent pulses when released into the river, with consequent increase in the risk of pollution effects. Although the 2000 m^3/second average discharge of the Jari River (Lang, 1979: 63) would appear to dwarf the effluent inputs, the head of the Brazilian Navy station at the site says at least one fish die-off has occurred downstream of the mill. The location of the mill near the mouth of the Amazon River is fortunate in limiting potential damage were water pollution to become a severe problem (and is also one of the many features of the Jari site not duplicable were the project to be copied elsewhere in Amazonia).

Jari maintains a pollution monitoring laboratory at Monduga, which submits reports of daily measurements of biological oxygen demand (BOD), disolved oxygen (DO) and other indicators to SEMA every week. SEMA also occasionally sends its own personnel to collect samples. The Jari River is classified by SEMA as "class 2"; applicable water quality standards for this category call for a BOD/5 days at 20°C of 5 mg/1 or less, and DO of at least 5 mg/1 in any sample (Brazil, Ministério do Interior, SEMA, 1976: 21).

Other Operations

Most of Jari's other operations, such as timber extraction for solid wood, kaolin mining, and irrigated rice, involve the destruction of natural habitats. Some, such as rice, involve the use of chemicals which can affect ecosystems beyond those altered directly in implanting the production system.

Jari's buyers are seeking government approval for several projects attempted by Ludwig but blocked by regulatory impasses. These include constructing a hydroelectric dam and importing a second pulp mill (*Veja*, 13 de janeio de 1982). Other projects contemplated by Ludwig, such as expanding the industial sector to produce paper on the site, might eventually also be realized if the various projects already in operation prove profitable.

Environmental risks of the various projects depend very much on how large they become. Jari's size (305 such estates would occupy Brazil's entire Legal Amazon) means that potential impacts at the local level merit careful monitoring.

General Conclusion

Jari's management policy must strive for indefinite sustainability, even though this implies higher current outlays. Among the preconditions required for sustainable management of the silviculture operation are: additional plantations to supply the fuel and pulp currently derived from native forest, an extensive research and monitoring effort, and the replacement of nutrients removed in harvested biomass. These changes do not assure Jari's future, although long term prospects are clearly bleak without them.

Silviculture, irrigated rice, and other sectors of Jari face biological and technical difficulties, as well as environmental risks. Hopefully informed debate on these issues will take place with an eye to minimizing the probability and potential impact of possible problems, and with the objective of contributing to wiser choices of development patterns offering a sustainable basis for serving human needs in the region[18].

GLOSSARY

ARCO	Atlantic Richfield Corporation.
CENA	*Centro de Energia Nuclear na Agricultura* (Center for Nuclear Energy in Agriculture), Piracicaba, São Paulo.
CNPq	*Conselho Nacional de Desenvolvimento Científico e Tecnológico* (National Council for Scientific and Technological Development), Brasília.
EMBRAPA	*Empresa Brasileira de Pesquisas Agropecuárias* (Brazilian Enterprise for Agriculture and Cattle Ranching Research), Brasília.
FAO	Food and Agriculture Organization of the United Nations, Rome.
INCRA	*Instituto Nacional de Colonização e Reforma Agrária* (National Institute for Colonization and Agrarian Reform), Brasilia.
INPA	*Instituto Nacional de Pesquisas da Amazônia* (National Institute for Research in the Amazon), Manaus, Amazonas.
IRI	IRI Research Institute, New York.
SBPC	*Sociedade Brasileira para o Progresso da Ciência* (Brazilian Society for the Progress of Science), São Paulo.
SEMA	*Secretaria Especial do Meio-Ambiente* (Special Secretariat of the Environment), Brasília.

NOTES

1. Jari Florestal e Agropecuária, Ltda. and Caulim da Amazônia S/A are now being integrated into the firm Companhia do Jari. The third Ludwig firm, São Raimundo Agropecuária Ltda., is not included in the sale, although negotiations are underway (*Veja* 27 de janeiro de 1982: 92).
2. This figure is Jari's last claim under Ludwig. Jari's new owners also claim 1.6 million ha (*A Crítica*, 13 de janeiro de 1982: 2), but have apparently so far only received assurances from the Brazilian government that 900,000 ha are theirs, with the "possibility of expansion" to 2 million ha (*Veja*, 13 de janeiro de 1982).
3. Jari's reported cash deficit in 1979 was US$ 150 million, the US$ 70 million in revenues (pulp + rice) being offset by operating costs of US$ 110 million, construction costs of US$ 50 million, and debt service costs of US$ 60 million. In 1980 the deficit was US$ 14 million, revenues of US$ 90 million being absorbed by operating costs in the pulp project of US$ 10 million, operating costs in the rice project of US$ 10 million, construction costs of US$ 20 million, and debt service of US$ 64 million (Kinkead, 1981). Other reports indicate the project lost US$ 80 million in 1980 on an operating budget of US$ 250 million (Brooke, 1981).
4. Proceeds from the sale will go to the Fundação Daniel Ludwig para a Pesquisa do Câncer (Daniel Ludwig Cancer Research Foundation) in São Paulo, plus a percentage of dividends distributed to stockholders through the year 2021: 5% for 10 years beginning in 1987, 4% for the next 10 years, and 3% for the last 15 years (*Veja*, 13 de janeiro de 1982). Note: the total debts of the project have been reported to be US$ 350 million (*Veja*, 16 de dezembro de 1981: 77), or US$ 170 million in addition to the remaining balance of the pulp mill loan.
5. From 5-12 November 1980 we observed commercial and experimental plantations of *Gmelina arborea, Pinus caribea* var. *hondurensis*, and *Eucalyptus deglupta*, and experimental plantations of various other species. Also visited were the nursey, pulp mill and power plant, mill effluent treatment ponds, wood transport and storage facilities, laboratories for soil, pulping research, and pollution control, herbaria, entomological and wood collections and other laboratories and technical offices. Other sectors observed were the *várzea* rice project, kaolin mine, water buffalo herd, beef cattle herd (in pastures in young pine plantations), and native forest extraction operations, as well as the native forest and the Jari and Araiôlos Rivers. We also visited the project in August 1978.
6. 60-90% standing crop ≥ 20 cm DBH. In over 400 species present, 230 are of same use. Of usable species, 82-86% can be utilized with *Gmelina* for pulp (Woessner, 1980a).
7. Various growth rates have been reported, but an average figure has apparently never been disclosed by the company. Kalish (1979) reports that "the exact growth rate was not disclosed by Jari foresters, but it is believed to be in the range of 25-35 m^3/ha/year for *Gmelina* and slightly lower for pine." One estimate, also made without benefit of production figures from the company, anticipated a mean yield of 25 m^3/ha/year for *Gmelina*, and 15 m^3/ha/year for *Pinus*. (Rollet, 1980: 8), and reported that 35 m^3/ha/year were "expected" from Eucalyptus (Rollet 1980: 14). Although Jari staff declined to estimate average yields for us as well, they stated that yields obtained on *good* soils were 35 m^3/ha/year for *Gmelina*, 25 m^3/ha/year for *P. caribaea*, and very approximately 40 m^3/ha/year for *E. deglupta*. It is worth noting that these *E. deglupta* yields are much higher than those reported for plantations in other tropical countries. In the Philippines, for example, a maximum of only 25 m^3/ha/year has been obtained (Tagudar, 1974 cited by Johnson, 1976: 208). Woessner (1980a) gives maximum yields at rotation age at Jari of 42 m^3/ha/year for E. deglupta 38 m^3/ha/year for *Gmelina*, and 25 m^3/ha/year for *P. caribaea*, but observes that "on less optimum sites the yields may be reduced by ½". Actually, on the least optimal sites the economic yield can be considered to be zero, since 20.7% of the plantation is reportedly "not managed" mostly due to poor soils (T.B. Svendsen and S. Lassen, personal communication July 1981). Jari's problem is that relatively little of the area is optimal, and it can ill afford to base calculations on the best possible yields. Average yields are much lower than the approximately 40 m^3/ha/year originally anticipated by Ludwig for the *Gmelina* he expected to use for the entire plantation: the areas now planted with P. *caribaea* instead of *Gmelina* can yield a maximum of 63% of this figure, probably yielding less over most of the area, while *Gmelina* and *E. deglupta*, although capable of achieving the expected yields on the best sites, fall far short on more typical solis. At more representative site indices for *Gmelina* on the order of 21, yields are around 20 m^3/ha/year (see note 10). One report gives *Gmelina* yields for sites of index 21 or over as 28 m^3/ha/year, expected yields of 20 m^3/ha/year for *P. caribaea*, and 20 m^3/ha/year (based on experimental plots) for *E. deglupta* (T.B. Svendsen and S. Lassen, personal communication July 1981). One earlier estimate, also made without benefit of production figures from the company, anticipated a mean yield of 25 m^3/ha/year for *Gmelina* and 15 m^3/ha/year for *Pinus* (Rollet, 1980: 8), and reported that 35 m^3/ha/year were "expected" (Rollet, 1980: 14). Very approximately, present yields on the order of half the original expectation seem probable over the estate as a whole.
8. According to Jari technical personnel, company laborers earn (Nov. 1980) Cr$114/day when calculated at 30 days/month paid for 13 months/year to include the extra month's salary standard in Brazil. They also receive production incentives averaging 30% of their total pay (but ranging up to 300%). This gives a total of Cr$57,798/year. Additionally, the company probably pays the standard benefits in Brazil: 22.33% in health insurance and social security, 8.33% in government medical assistance, and 8.33% for disability leave allowance. These would increase the cost to the company to Cr$75.132/worker/year, or Cr$262.70/day worked using a 286-day year (discounting Sundays and a one month paid vacation), or US$4.24/worker/day worked at Cr$62/US$ (Nov. 1980).

9. According to mill officials, 20% represented a goal for 1981, and 30% of the power generated was coming from fuel oil as of 1980. Some oil generated power must be used as a supplement to maintain even power output in the face of inevitable variation in the energy supply from burning wood chips.

10. The site index represents an estimate of the average top height in meters of the 100 tallest trees in a stand at age 10 years. Jari has gradually increased the site index at which *Gmelina* stands are converted to other species, either immediately or at the end of a cycle. Most recently, sites of index 19 or over are allowed to resprout for further *Gmelina* crops, but new plantings of *Gmelina* are only made on sites of index 21 of above. Sites of indices of approximately 15 to 18 are kept in *Gmelina* until harvested, and then converted to ***P. caribaea*** or ***E. deglupta. E. deglupta*** is planted on sites with index 13-17 and ***P. caribaea*** on sites with indices below 13. Jari finds *Gmelina* yields relate to site indices as follows (R. G. Lowe, personal communication, 1981), assuming a 6 year rotation site index: metric/tons wet inside bark yield/ha/year): 13:7.7; 15:8.1; 17:11.5; 19:14.7; 21:19.3; 23:22.8; 25:26.5; 27: 30.5. Note: Jari staff use appoximate *Gmelina* wet density of 1 metic ton/m^3.

11. The long term availibility of phosphate rock is a matter of debate. One study (Institute of Ecology, 1972) indicates that phosphate rock of a least 8% P (currently mined deposits contain 12% or more) would last until 2062, based on continued exponential increase (5.25%/year) in phosphorus fertilizer use. The assumption of continued trends at this rate has been criticized as overly pressimistic (Wells, 1976). Population and cultivated area cannot expand unchecked. Although obvious that the historical exponential increase in phosphate use cannot continue for long, the eventual lowering of use rates will probably be tied to unprecedented price increases.

12. The relation of plantation area to the number of pests follows logically from island biogeographic theory (MacArthur and Wilson, 1967). Examples include that of sugar cane native to New Guinea: an isolated one hectare patch in Iran 800 years old has only pest, whereas Brazil's substantial cane areas have 50-60 different pests (W. W. Benson, Statement at SBPC meeting, Fortaleza 1979). ***Eucalyptus*** plantations in Brazil's state of Minas Gerais have experienced increasing insect pest attacks as local insects have adapted to the new species (Moraes ***et al.***, 1982). Municípios with older plantations have more severe pest problems, as do municípios with over 5% of the land area planted to ***Eucalyptus*** (G.W.G. Moraes, presentation at SBPC meeting, Campinas, 1982).

13. Many people do not realize the rapidity with which the cumulative probability of an event increases, even when the annual probalitiy is quite small. An event with a 1% probability of occurrence per year, for example, has a more than 50% chance of occurring within 69 years. A 2%/year risk would reach this level in less than 35 years.

14. December 1980 pulp prices of US$ 322/metric ton on the Brazilian internal market, as compared with US$ 515/metric ton at European ports, mean that the 20% of output required to be sold within Brazil, at the 750 metric ton/day nominal capacity, represents a loss of US$ 10.4 million/year, less a relatively small amount for difference in shipping costs.

15. The cattle herd is reportedly being slaughtered, without replacement, to feed Jari's work force during the current economic crisis (C.F. Russell, personal communication, Oct. 1981).

16. The good results of the pasture/pine interplanting raises the important possibility of pine plantations as a potential use for the extensive areas of fast-degrading pastures throughout the Amazonian *terra firme*. It is worth remembering two points of caution: 1) if an enterprise wished to establish a pulp operation following the Jari pattern, the native forest would represent a valuable source of fuel and supplementary pulpwood, making it more attractive to entrepreneurs to establish such plantations on currently forested areas rather than cattle pastures, and 2) many of the negative features of cattle pastures remain (effects on rainfall, income distribution, employment, etc.), and 3) pine plantations also have deleterious effects on the soil and undemonstrated long term sustainability. Although pastures supplanted by ***Pinus caribaea*** are more economically and socially desirable than pastures supplanted by second growth, care must be taken not to foster illusions either that a way has been found to make pastures sustainable, or that the various negative aspects of pasture as a development option have ceased to be preoccupations. Above all, such very praiseworth efforts to improve pasture management must not be used as a rationalization for encouraging the clearing of more of the Amazon's rain forests for pasture. With these warnings in mind, the pasture/pine experience at Jari should be a valuable demonstration of one way to make use of those parts of the Amazon ***terra firme*** which have ***already*** been cleared for cattle pasture (see Rankin, 1979).

17. In late 1981 the Kaolin operation was shut down temporarily due to a drop in world prices, but is expected to resume normal operation soon (C.E. Russell, personal communication, Oct. 1981).

18. We are grateful to the National Council for Scientific and Technological Development. (CNPq) for providing travel funds through the National Institute for Research in the Amazon (INPA). We thank the Center for Nuclear Energy in Agriculture (CENA) for analyzing our soil, water, and vegetation samples. This paper in no way represents the views of CNPq, INPA, or the many colleagues with whom we have discussed the developments at Jari. Any errors are our own responsibility.

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