JARI REVISITED: CHANGES AND THE OUTLOOK FOR SUSTAINABILITY IN AMAZONIA'S LARGEST SILVICULTURAL ESTATE

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The period since the silviculture and mining operations of the Jari project came under Brazilian management in January 1982 has been one of rapid change. We have previously examined this 1.6 million hectare estate in the northeastern portion of the Brazilian Amazon from the point of view of providing a potential development model for wider areas of the Amazon region, and from the point of view of the prospects of the Jari enterprise itself at the time that the North American shipping magnate D. K. Ludwig sold a controlling interest in the silviculture and mining operations to a consortium of Brazilian firms (Fearnside and Rankin, 1980, 1982). On a recent visit to Jari (July 20-26, 1983) we found that since those reports many changes have occurred. The changes, some of them substantial and some of them small, potentially affect the long-term sustainability of silvicultural and agricultural production at Jari and in the Amazon region. We use the term "sustainability" to refer to permanent maintenance of biological productivity on the site, with the costs of imported supplements of energy, nutrients and other inputs not exceeding the commercial value of the site's production. Several of the potentially grave problems we warned about earlier have, unfortunately, been confirmed by subsequent developments. The new management has embarked on an accelerated program of maintenance activities and new planting (Fig. 1) in order to reverse the deterioration of the estate that occurred during the transition period and to make the undertaking profitable to its new owners. Among the prerequisites for long-term sustainability of the plantations, research has not received equal attention.

Changes and Outlooks

Plantations

Profound changes in plantation management have been motivated by the unremitting spread of the fungal disease caused by *Ceratocystis fimbriata* in *Gmelina arborea*, formerly the principal silvicultural tree species. The cancre caused by the disease was first detected in the plantations in 1976 (Muchovej *et al.*, 1978). When we observed the disease in 1978 and warned of its potentially devastating impact, it had affected only a tiny fraction of the *Gmelina* plantations (Fearnside and Rankin, 1980). By our second visit to Jari two years later, the disease had spread to many parts of the plantation, and we have since learned that the (previous) company's policy forbade staff members to discuss the true extent of *Ceratocystis* attack at that time (1980). Since 1980 the disease has become very obviously more serious. The silvicultural staff estimate that plantation productivity was lowered 14% per year after the fifth year of *Gmelina* growth, leading to a decision to shorten the *Gmelina* rotation from six years to five. Since most of the cost of plantations is in planting, harvesting and the weedings of the first years of growth, the change will substantially increase the cost of each ton of *Gmelina* produced.

Another response to the *Ceratocystis* problem has been to abandon plans for allowing the stumps of harvested *Gmelina* to resprout for a coppice crop in some areas. Coppiced *Gmelina* appears to be attacked sooner and more severely than trees planted as

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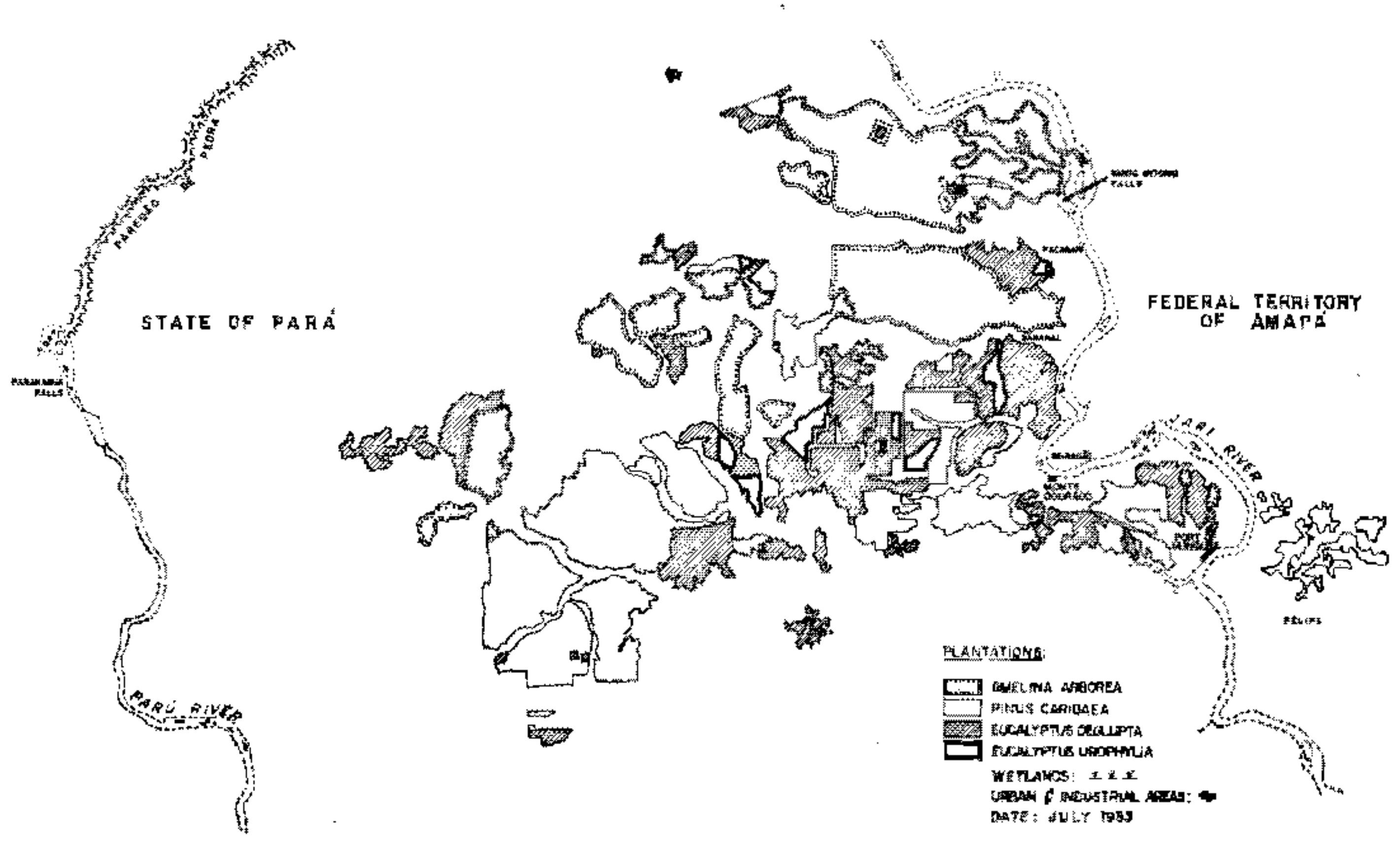

Fig. 1. Locations of Jari plantations.

seeds or seedlings. Other factors believed by some of the staff to reduce *Ceratocystis* attack include planting on virgin forest soil rather than in previously planted areas and burning slash from harvested plantations in the second cycle plantings. Burning can be done only in those areas harvested during the dry season. Spraying with fungicides would be uneconomic on a commercial scale and has only been done in *Ceratocystis* - killed trees removed from the *Gmelina* seed orchard.

Little progress has been made on determining the epidemiology of *Ceratocystis*. The technical staff no longer believe that pruning was a significant factor in the spread of the disease. An as-yet uncaptured insect vector is suspected, with transmission hypothesized to be similar to that of Dutch elm disease in the United States.

An effort to identify *Ceratocystis* - resistant lines of *Gmelina* is just now being started. Although other goals of this genetic improvement program at Jari, such as straightening *Gmelina* trunk form, have met with spectacular success, progeny of some trees have proven to be more resistant than others, however a satisfactory resistant strain has not yet been identified.

The biggest and most costly effect of the *Ceratocystis* problem is the decision to phase out *Gmelina* in favor of *Eucalyptus* species in much of the area with soils adequate (but not excellent) physical and chemical properties for *Gmelina* growth. The staff suggest that if the disease losses become more severe in the future, it may be necessary to discontinue *Gmelina* entirely. The Company is reluctant to take such a move, since *Gmelina* pulp has been the hallmark of Jari and forms the basis for the estate's reputation for high quality pulp. *Gmelina*, which produces a short fiber pulp ideal for expensive art papers and glossy magazines, competes directly with Scandinavian birch for the top of the market. *Eucalyptus* pulp, more suitable for cheaper grades of paper, commands a substantially lower market price per ton. Large *Eucalyptus* plantations in other parts of Brazil pose a competitive threat, since *Eucalyptus* grows no faster at Jari than it does in the state of Minas Gerais, while costs are higher. This indirect cost of the *Ceratocystis* attack in *Gmelina* may therefore be heavy when *Eucalyptus* becomes a major product of the enterprise beginning in approximately 1985.

Another indirect cost of the *Ceratocystis* attack may become an economic drain only in the longer term, but its effects could be both severe and permanent. This is soil erosion. In an effort to eliminate resprouting *Gmelina* stumps from areas to be diverted to other species or to be planted in *Gmelina* from seeds or seedlings, heavy machinery has been used to pile native forest logs and plantation remains into windrows, allowing an "intensive site preparation" by raking with tractors before planting. Unfortunately, the *terra roxa* (Alfisol) soils most suited to *Gmelina* also tend to occur on the more steeply sloping terrain, mostly in the northern portion of the estate (Figs. 2 and 3). The Company has foregone using heavy machinery on the steepest slopes, but it has done windrowing and intensive site preparation on slopes up to approximately 20% in the *Gmelina* areas. Gully formation and sediment transported by sheet erosion are readily apparent in those areas replanted to *Gmelina* (such as Block 62-83), as well as in similarly mechanized former *Gmelina* areas planted to *Pinus caribaea* (such as Block 45-83).

Windrowing, necessary due to the aggressively resprouting *Gmelina* stumps, removes valuable nutrients from the more fertile surface soil layers and the decomposing biomass. The use of heavy machinery also compacts the soil, a factor found to retard *Gmelina* growth when bulldozers were used in clearing native forest during the early years of plantation establishment at Jari (Fearnside and Rankin, 1980). Soil compaction generally increases erosion by reducing infiltration, thus leaving a larger fraction of rainwater to become sediment-carrying runoff. The Company's policies regarding use of heavy machinery have changed a number of times since soil compaction led to a switch to manual felling of native forest in the mid-1970's. The practice of using bulldozers for felling operations has never returned, although skidders are used to drag logs felled in native forest to the roadside as clearing proceeds. Skidders were also used to transport harvested pulpwood to roads in most parts of the estate until 1982, when the practice was discontinued in favor of hauling bundles of pulpwood on cables drawn by winches on "Big sticks" — Mercedes-Benz trucks equipped with small cranes (See Fraser, 1981). Previously, "Big sticks" were used only on the steepest terrain. Harvesting with skidders is a cheaper method but damages the land by soil compaction and creation of formidable trenches when these heavy rubber-tired vehicles become mired in soft earth during rains. The change in method did not take place until three years after the ill effects of skidders were noted in 1979 during the estate's first commercial harvest, despite a running battle over the issue between the forest management and the harvesting sectors of the Company. The delay in changing harvesting methods, allowing damage to be done to the soil of a substantial part of the estate, is an indication of the almost total discounting of long-term productivity during the final years of Jari's previous management.

Soil compaction has become a problem in slowing the growth of trees in the second cycle plantations in the log patios or "decks" —areas which served as collection and loading points for pulpwood harvested at the end of the first rotation. The deck areas are readily apparent from the stunted appearance of planted trees as compared with surrounding areas.

The use of fertilizers is a significant change in the management program at Jari. Fear of an impending shortfall of wood supply for the pulp mill, as well as concern over early growth and survivorship of newly planted seedlings and the shift to *Eucalyptus*, led the estate's managers to invest in fertilizing seedlings of *Gmelina* and *Eucalyptus*, beginning in 1982. Fertilizer is applied only once, at the time of planting. Jari used 2300 metric tons of fertilizer in 1982 at a rate of 250 kg/ha (150 g/plant at the 1667 plants/ha density used). The 1982 mixture of 8:31:5:0 (nitrogen: phosphorus: potassium: micronutrients) was altered to 8:30:5:1 in 1983, maintaining the same dosage per hectare. The February 1983 price paid by Jari for this fertilizer mixture at Belém was US$62.97/ha, plus the costs of transporting the fertilizer from the port of Belém and of 3 man-days/ha for application. The use of outside nutrient supplements, not previously considered by management, represents a major change. It is important to note that dosages, as in agronomic practice generally, are calculated based on what managers feel will give the best return on money invested in the following crop, rather than being determined by the amounts needed to balance outflows through harvesting and other channels. The substantial outlay, calculated at US$134/ha/year for *Gmelina* (Fearnside and Rankin, 1982: 131) that would be needed to achieve such a balance is clear from chemical analyses of *Gmelina* (Fearnside and Rankin, 1982; Fyfe *et al.*, 1983: 396) and *Pinus caribaea* (Jordan and Russell, 1983).

Another major change in plantation management was an increase in the number of different pulpwood species planted commercially on the estate. *Eucalyptus deglupta*, first started on a small scale in 1979 and occupying 1425 ha by 1980, had increased rapidly to nearly 20,000 ha by 1983. *Eucalyptus urophylla*, which was showing better growth than *E. deglupta*, was first planted commercially on a small scale in 1982 (experimental testing began in 1980), and has been rapidly expanded, reaching 8065 ha in 1983. Among other advantages, *E. urophylla* has proved more drought resistant and more uniform in growth than *E. deglupta* to date.

Several other species were under testing for possible future commercial planting. *Eucalyptus camaldulensis* appeared more drought-resistant and faster growing than either *E. deglupta* or *E. urophylla*. One must be very careful in using the initial growth of a plantation species as an index to its final yield, however, as many species grow rapidly in the first year only to slow down later. This was the case with *Gmelina* when planted on the sandy soils in the southern portion of the Jari estate (See Fearnside and Rankin, 1980).

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One must also be extremely careful about extrapolating the results of experimental plantations to full-scale commercial plantings. Using results from very small plots, and especially line plantings, can be misleading, since the dominance of edge effects makes the outcome highly dependent on growth of the test species during the first months relative to the initial growth of species in adjacent plantings. Results can also be affected by the tendency of small experimental plantings to receive better control of weeds, pests and other problems than do the commercial plantings they are intended to simulate.

Planting of *Eucalyptus deglupta*, for example, was launched on a commercial scale largely on the basis of impressive growth in a line planting trial (Block 74-77, Plots 21A&B). As we pointed out at the time commercial planting began, this species is prone to highly uneven growth, with the few best-growing individuals being a poor index to average performance (Fearnside and Rankin, 1982). Subsequent performance of the species at Jari has proved this to be correct, uneven growth being the norm in *E. deglupta* stands. Greater investment in screening a wide range of potential plantation species and provenences in order to identify species less susceptible to intraspecific competition might have paid off handsomely. Since the cost of establishing and maintaining commercial plantations is quite high, as well as being fairly similar regardless of the species planted, the choice of a species or variety which raises gross productivity by, say, 10% would represent a far greater increase than this in profits to the enterprise. Money invested in species and variety selection would be well spent.

In the case of *Eucalyptus deglupta*, a mistake was made in seed selection for rapid expansion of the plantations. Rather than obtaining seed from established foreign sources, the financially pressed Company collected seed from the early flowering trees in their own young commercial plantations. The result was the selection and widespread propagation of an undesirable genetic trait: precocious flowering. When *Eucalyptus deglupta* flowers at an early age, often in the first year and sometimes even as seedlings, in the nursery, the tree's vegetative growth is slowed. Early flowering also results in an undesirable "dog leg" form in the trunk.

Most of Jari's current species testing centers on trials of different members of the genus *Eucalyptus* rather than native Amazonian species. None of the native species trials has resulted in commercial plantings. One reason is the greater number of pests that can be expected to attack native species as compared with recently introduced exotics. One species under trial, known locally as *"Pará-Pará" (Jacaranda copaia)* has shown good growth at Jari but has almost invariably had its trunk cut off at a height of approximately nine meters by an *Hypsipyla* shootborer (pit moth larva). The same problem has occurred in experimental plantings at Belterra, Pará, although it has not yet occurred at Manaus, Amazonas. The result of shootborer damage is poor form, as a ring of lateral branches substitutes for the main trunk above the point of attack. Nevertheless, the spontaneously occurring individuals of Pará-Pará in unfertilized *E. deglupta* planted in 1981 are being retained for eventual harvest.

Trials on a second potential native pulpwood species, the *"munguba" (Bombax munguba)*, began only in 1983. Other native species, such as *Laetia procera* have been identified as having oustanding characteristics for pulp, but have received no silvicultural investigation. The copious natural regeneration of *Laetia* in newly-cleared lands and disturbed forests (J. M. Rankin, in preparation) suggests that an alternative may exist to plantation monocultures as an exclusive pulp source at Jari.

Drastic reduction of Jari's research staff, mainly occurring in the period immediately preceeding the transfer of control to the present consortium, is a measure that risks serious setbacks in the long term. Not only can the gradual improvement of genetic lines and management techniques justify a substantial research investment, but the adequate testing of new species provides the best insurance against costly mistakes or inability to adapt to changing disease and pest problems. Research staff has been reduced from 14 to 1. The soil monitoring program has been suspended since 1981. The area of new experimental plantings installed each year gives some indication of the extent of research effort. In 1978, 195 ha were installed; the figure then fell to 80 and 99 ha in 1979 and 1980, the period during which Ludwig's cash restrictions became more serious. Experimental plantings fell to zero in 1981, the year of the ownership transition. In 1982, the second year of the new management, 24 ha were planted. Jari's managers hope to increase the research staff to a modest level in the future.

The number of squatters present in the Jari area has increased precipitonsly since 1980, a change readily apparent when traveling through the plantations. The Company estimated that 1500-2500 squatter families were present by 1983. Most have selected sites near roads or navigable rivers. Squatters have favored areas with the most fertile soil type, *"terra roxa"* (Alfisol). While the area occupied by squatters remains relatively small, this may change in the near future due to the rapid increase in the number of families, together with the need to rotate plantings over an area of land much larger than that planted in any given year, in order to maintain productivity of annual crops. The losses caused to Jari's silvicultural operation by the presence of squatters are many times those implied by the direct withdrawal of potential plantation area. The principal problem is the increase of fire in the plantations. When the squatters burn the cut vegetation during the dry season in preparation for planting, the fires often spread to adjacent silvicultural plantations. *Pinus caribaea,* with its combustible mat of dead pine needles and retained dead lower branches, and *Eucalyptus* species, with their high content of flammable oils, are particularly susceptible. During the 1982/1983 dry season, which was a particularly long one, 4-6 fires were usually burning on any one day over a period of several months. The technical staff estimate that only 200-300 ha were lost to fire during the season, but credit such a low figure to extremely good luck. Many of the plantation fires were started by squatters preparing their fields, including those responsible for the greatest plantation losses.

Resolution of the squatter situation has been hindered by the estate's continued failure to gain legal confirmation of its land claims. The Brazilian government's interest in removing bureaucratic impediments to development at Jari, as indicated during the July 1983 visit to the project by Minister of the Interior Mário Andreazza, may eventually lead to breaking such long-standing impasses.

Jari has discussed various schemes for resettling squatters in areas removed from the silvicultural plantations, but no definitive decision has been taken. Economically crippling losses to fires are quite possible if the situation is not resolved in a way which provides ample margin between small farmers and the silvicultural plantations. The "good luck" of past fire control programs cannot be counted on to protect the estate from losses, especially as the number of squatters increases and the transition continues from *Gmelina* to more flammable tree species.

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Pulp Mill

Gradual improvements have been made in the industrial processes employed at the pulp mill. The mill now produces 750 metric tons per day, a level well above its 700 metric ton nominal capacity. When pulping *Gmelina*, which has a higher yield than the *Pinus caribaea* being used in the current mill cycle, maximum production has occasionally reached almost 900 metric tons/day for brief periods.

The reduction of unpleasant smelling air pollution at the mill site is readily apparent. The staff attribute the reduction to improvements made in the milling process.

A tiny fraction of the solid residuals produced by the mill is now collected in trucks and utilized as fertilizer (Fig. 4). This is an important change in principle, even if relatively insignificant as a nutrient pathway. The vast majority of nutrients removed in the harvest are neither returned to the plantations nor exported in the final product, but are simply discarded. All of the bark, where most of the nutrients are concentrated, is burned (Fig. 5).

The pulp mill, and the silvicultural operation as a whole, is highly dependent on the price of pulp. The market has partially recovered from a major depression of pulp prices that added greatly to the Company's financial problems. The price per metric ton for pulp on world markets stood at ronghly US$500 in 1980, but fell to US$320 at its low point in 1982, and rose to approximately US$400 in July 1983.

Native Wood

Wood from felling native forest (Fig. 6) is still an important source of supplementary material for pulping, fuel for supplying power to the factory and city, and timber for export. The amount of wood harvested has decreased as the project's expansion has slowed. Felling of native forest slowed from approximately 5000 ha/year in 1980 to 1750 ha/year in 1983. The reduced volume of wood affects its marketability as an export commodity, since timber dealers are often more interested in the volume of any given species available than in the positive or negative aspects of the wood itself. If a sufficient volume is available, a market can be found for virtually any wood (Henk Rodenhuis, personal communication, 1983). Timber marketing has also been affected by a change in the composition of the forests being harvested with a switch from clearing on the Pará side of the Jari River to the Amapá side. The "angelim vermelho" (referring to trees in two genera of the "angelim" common name groups: *Dinizea* and *Hymenolobium*), provides an example. This much-sought group of species (*World Wood*, 1981) is much more common in the forests of the Pará portion of the estate. The change in location and slowing of felling have decreased the harvest of this species from 76,000 m³/year to about 700 m³/year (Henk Rodenhuis, personal communication, 1983).

The redneed flow of wood from clearing for new plantations has been partially compensated by wood obtained from other sources. In 1983, areas in Jari's "Bananal" sector (located in the north-central section of the Pará portion of the estate) have been logged for "thin" logs for use as pulp and fuel, but not lumber. The larger trees in this area are left standing. The area may be used for a settlement scheme for re-located squatters, but no final decision has been made; otherwise it may be used for plantations at a later date.

A second source of supplementary wood is obtained through contractors who tow rafts of logs from assigned riverside territories. The logging territories extend along both sides of the Jari River from San Antonio Falls to the confluence with the Amazonas River, the left bank of the Amazonas between the Jari and Parú Rivers and the left bank of the Parú River to the Paranaguá Falls (See Fig. 1). In a typical week (July 1-7, 1983) Jari harvested 22,046.82 metric tons of native wood, of which 13,715.41 metric tons (62.2%) came from felling for plantations in Amapá, 7,890.26 metric tons (35.8%) came from the selective felling at Bananal, and 441.1 metric tons (2.0%) came from the contractors logging in "várzea" (floodplain) and easily accessible upland areas along the rivers.

The number of tree species used is gradually increasing, and testing continues on new species potentially usable for pulpwood or hogfuel. As of 1983, 80 species were used for pulpwood. Upland forest felled for plantations typically yields approximately 350 metric tons/ha (wet weight) of logs over 10 cm diameter at breast height (DBH). About 10% of the weight is used for pulping, 60% for hogfuel, and 30% for the sawmill. An additional 50 metric tons/ha are represented by large branches which can be collected for hogfuel. Tree species too dense for chipping, plus fine branches that cannot be used at present, account for something over 100 metric tons/ha.

Experimentation is underway to assess the feasibility of making charcoal using fine branches and species too dense for chipping. Charcoal produced so far is of a high quality suitable for export for the market in industrialized countries for barbecue charcoal and brickettes. Pulverized charcoal may also be used at Jari to replace diesel oil in heating the lime kilns associated with the pulp mill, necessary for producing the caustic soda (NaOH) used in the pulping process.

Mining

Kaolin (China clay) mining continues. The mine provides a profitable sideline for the Company while requiring relatively little overhead.

Crushed rock is now being quarried in the Pacanarí area located in the northeastern part of the developed portion of the estate's holdings in Pará. Transport is greatly facilitated by the excellent railway and port facilities already in place for the silvicultural operation. The rock is used in railway bed construction in western Pará for the bauxite mining project Mineração Rio do Norte (Trombetas). Crushed rock has been exchanged upon occasion for limestone (from Monte Alegre, Pará), needed as an input for Jari's pulpmill.

Gold mining within the area claimed by Jari has expanded from relative insignificance to a booming pirate industry. The deposits lie outside of the area usable for plantations. Gold strikes have been made along the streams to the north of the paredão ("great wall") geological fault which forms the wall-like northern limit of the plateau where most of the company's plantations on the Pará side of the Jari River are located. The deposits are within the 1.6 million hectares claimed by Jari, but outside of the 600,000 ha for which the Company's legal documentation is most secure. The deposits are worked by small, unauthorized prospectors, who use as their base of support the "Beiradão" shanty-town across the river from the town of Monte Dourado. They use the medical and other social services in Monte Dourado provided free of charge (so far) by the Company to all residents of the area. Transfer of all medical services to the Brazilian government's Public Health Service Foundation (FSESP) is anticipated in the near future.

No mining of alnmina bauxite has been done, and construction of the 22 km rail spur planned for the alumina deposit area has been postponed indefinitely. A deposit of the more valuable refractory (fire-brick) bauxite located at the same site (See Fraser, 1981) also remains unexploited.

Fig. 2. Steeper slopes, where Jari's better soils occur, are susceptible to soil erosion, especially where mechanized land preparation is used as in this site converted to genetically improved *Gmelina* (Block 62-83).

Fig. 3. Eroded soil under young *Gmelina* (Blocks 62-83).

Fig. 4. A small part of the pulp mill's residuals is now collected in trucks and returned to the plantations.

Cattle

Jari has discontinued the practice of planting pasture in new *Pinus caribaea* plantations, although 5000-8000 ha of established *P. caribaea* with pasture are still present on the estate. The decision to discontinue the combination was based on the urgent priority to maximize pulpwood production in order to keep the mill supplied, and on the added expense of producing cattle in pine rather than in pasture monocultures. The fact that *Pinus caribaea* retains its dead lower branches as the trees grow means that the stands would have to be pruned and weeded in order to make cattle management viable. A small area of pine has been pruned and cleaned at the expense of the Company's livestock department (rather than the forest management department), but the expense, which would be unnecessary in the absence of pine, is not jnstified from the silvicultural management point of view. The costs of keeping livestock in pine plantations are also high, since cattle can be kept in the plantations only from the second through the fifth year of growth, or 3 years out of a 12 year rotation. The expense of fences, corrals, and other infrastructure is

Fig. 5. All of the bark, here being removed in Jari's debarker, is still burned. Since nutrients are conceotrated in the bark, most are lost from the system.

Fig. 6. Wood from felling native forest, used as fuel and to supplement pulpwood production, must eventually be replaced by production from more costly plantations.

been present in small numbers in previous years but had never become an economically damaging pest. Various possibilities have been suggested as explanations of the explosion, including the extremely dry weather of 1983, and a change in land preparation methods instituted in 1982: the practice of passing a deep-cutting puddler *(rolo faca)* over the paddies was discontinued in favor of using tractors with cage wheels. There are also large snail populations in the unplanted *várzea* outside of the rice production area. The effect of the snails can easily be observed as open patches of water scattered through the paddies of growing rice. Most of the openings are small, however production staff members note that some are as large as one hectare. The staff say that no estimate of overall losses has been made, although individual production blocks have lost as much as 5% of their standing rice. The snails multiply rapidly, and a monitoring program has been established to detect foci of small snails before they reach their full size (adult shell length is 6-7 cm). Control is attempted by adding copper sulfate ($CuSO_4$) solution directly to the irrigation water. Success has been varied, the potency of the solution differing greatly depending on the commercial source. While almost all adult snails can be killed in treated paddies, not all paddies have been treated and the population of snails continues to increase, according to the reports of fieldworkers responsible for individual blocks.

The principal insect problems of rice at São Raimundo are the borers *Rupella aubinela* and *Diatrea saccarale*. These are controlled with two applications per crop of Furadan (carbofuran). This systemic insecticide also controls army worms *(Spodoptera frugiperda)* and stink bugs *(Debalus poecilus)*. As with fungicides, the increased use of insecticides, reflected in the adoption of a regular schedule of spraying rather than applications on an "as needed" basis, is expensive but not unexpected.

The principal weeds are *Thalia geniculata* (Marentaceae) and *Cyperus* spp. (Cyperaceae), both present since before 1980. *Leptochloa* (Graminae) is now present but responds well to the regular applications of Stam (propanin or propanil) herbicide.

The problem of teals (probably the Brazilian teal: *Anas* spp.), know locally as "marrecas", has increased in recent years. These birds are most damaging in areas bordering on the uncultivated vegetation of river margins. They are also a greater problem during the wet season, when dry land in surrounding areas is unavailable. One countermeasure has been to leave some fields dry to attract the birds away from planted areas. Another has been to employ workers to shoot shotguns at regular intervals in an effort to frighten them away.

Egrets (Ardeidae) have also been increasing recently. Although these birds do not eat rice directly as do the teals, their wading damages small plants.

The Company has given up its incipient plans for using various non-rice cultigens as rotation crops. Also abandoned are plans to obtain a ratoon (stubble) crop of rice between the two principal crops by changing the variety of the principal crop to J-226. Plans are being made, however, to try planting a short-cycle rice variety (J-369, with a cycle of 85 days) between the two principal crops of the current commercial variety (J-229, with a cycle of 110 days). The trial was to be installed in late 1983 in a 32 ha area of the commercial plantation.

The rice project's expansion program has continued slowly, increasing the cultivated area from 3062 ha in 1980 to 3500 ha in 1983. This has been done by bringing as-yet undeveloped portions of the first phase of the project into production. About 600 ha remain that can be developed in this way, taking advantage of the canals and dikes already in place. Further expansion to the full 14,165 ha originally planned for the project would require the construction of additional infrastructure.

The original large rice fields (500 m wide) continue to be bisected into smaller ones where water management can be done more quickly and easily. The pace has been slower than originally planned, and the entire area will not be converted by the end of 1983, as expected earlier. The program competes with area expansion for the use of equipment, although canals can be built at any time of year while new areas can be prepared only in the dry season.

A change in the way problems are monitored in the field took place in 1982. Rather than a system of regular observations by Company staff to assess levels of insects, diseases, and other problems, a group of fieldworkers has been given a short training course. Each responsible person, known as an *arrozeiro*, is given responsibility for a single rice block and is to use a "feel" for rice culture to identify problems and alert the administration to needs. So far the administration is pleased with the results, for example in following the problems of snails and teals.

Rice yields for the two crops in the 1982/1983 agricultural year averaged 4.75 metric tons per hectare per crop, according to the technical staff. Yields for 1981 and 1982 were not revealed. The 1982/1983 yields compare favorably with the approximately 4 metric tons per hectare per crop obtained in 1980, a production level that also characterized the operation before the agricultural problems of 1979, when yields fell to about 3.5 metric tons per crop (See Fearnside and Rankin, 1982).

> The number of squatters present in the Jari area has increased precipitously since 1980, a change apparent when traveling through the plantations. The Company estimated that 1,500-2,500 squatter families were present by 1983.

The fertilizer doses per crop in 1983 have stabilized at 120 kg/ha N, 40 kg/ha K, 40 kg/ha P and 12 kg/ha S. For comparison, the doses per crop in 1980 were 120 kg/ha N, 26-44 kg/ha P, 60-66 kg/ha K, and 275 kg/ha S (supplied with the N as ammonium sulfate).

The rice project, in summary, has continued to cope with a changing array of agricultural problems. Use of chemical inputs such as fertilizers, insecticides, and fungicides has increased as predicted (Fearnside and Rankin, 1980, 1982). While the number of biological problems affecting the rice has risen, increased expenditures on control measures have so far prevented major losses. The greatest risk to long-term sustainability is the current suspension of research, especially rice variety testing so that new cultivars will be available when future changes in the types, numbers and resistance of pest and disease organisms eventually negate the present chemical controls.

General Conclusions

The principal threats to the silvicultural operations at Jari in the short and medium terms include (1) the spread of the *Ceratocystis fimbriata* fungus in the most valuable commercial tree species, *Gmelina arborea*, (2) economic competition from other parts of Brazil for the *Eucalyptus* pulp market, and (3) rapidly increasing fire hazard from the agricultural activities of squatters adjacent to the silvicultural plantations. Long-term problems are likely to include soil degradation from erosion and soil compaction, and decline of nutrient stocks relative to newly cleared areas. The greatly increased costs accompanying the eventual exhaustion of native forest will also only be felt in the long term. Drastic reduction of the research and monitoring efforts at the estate place the operation in danger of being unable to adapt to future biological problems requiring different species or management techniques.

On the positive side, the estate has diversified its plantings significantly in relation to its past history, although it would be wise to continue increasing the number of different species planted commercially. Several management changes, for example in harvesting procedures, are less damaging than previous practices.

The separate irrigated rice operation has a similar set of problems, including increased disease and pest attacks, increased chemical inputs, and a suspension of research activities that may seriously jeopardize the sustainability of the operation when future problems arise.

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REFERENCES

Fearnside, P. M. (1979): Cattle yield prediction for the Transamazon Highway of Brazil, *Interciencia* 4 (4): 220-225.

Fearnside, P. M. (1980): The effects of cattle pastures on soil fertility in the Brazilian Amazon: consequences for beef production sustainability, *Tropical Ecology* 21 (1): 125-137.

Fearnside, P. M. (nd): Agriculture in Amazonia, In: G. T. Prance and T. E. Lovejoy (eds.) *The Amazon Rainforest*. Key Environments Series, Pergamon Press, Oxford, U. K. (in press).

Fearnside, P. M. and J. M. Rankin, (1980): Jari and development in the Brazilian Amazon, *Interciencia* 5 (3) 146-156.

Fearnside, P. M. and J. M. Rankin, (1982): The new Jari: risks and prospects of a major Amazonian development. *Interciencia* 7 (6): 329-339.

Fraser, H. A. (1981): Jari pulpwood harvesting boosted with "Big Sticks". *World Wood*, 22(6): 24-26.

Fyfe, W. S., B. I. Kronberg, O. H. Leonardos and D. Olorunfemi, (1983): Global tectonics and agriculture: a geochemical perspective, *Agriculture, Ecosystems and Environment* 9 (4): 383-339.

Hecht, S. B. (1981): Deforestation in the Amazon basin: practice, theory and soil resource effects. *Studies in Third World Societies* 13: 61-108.

Hecht, S. B. (1983): Cattle ranching in the Eastern Amazon: environmental and social implications, pp. 155-188. In: E. F. Moran (ed.), *The Dilemma of Amazonian Development*, Westview Press, Boulder, Colorado, 347 pp.

Jordan, C. F. and C. E. Russell, (1983): Jari: productividad de las plantaciones y pérdidas de nutrientes debido al corte y la quema, *Interciencia* 8 (5): 294-297.

Muchovej, J. J., F. C. de Albuquerque and G. T. Ribeiro, (1978): *Gmelina arborea* a new host of *Ceratocystis fimbriata*, *Plant Disease Reporter* 62 (8): 717-719.

World Wood (1981): New tropical hardwoods hit at timber fair. *World Wood*, 22 (1): 28.