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RETHINKING CONTINUOUS CULTIVATION IN AMAZONIA

Subhead: The "Yurimaguas Technology" may not provide the bountiful harvest predicted by its originators

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The land surrounding the Amazon River is often viewed as a potential cornucopia, which could allow South American nations to thrive despite continued population growth and poorly-distributed resources. A set of recommendations to increase agricultural productivity of this region is under trial at Yurimaguas, Peru (Nicholaides et al. 1985). This "Yurimaguas technology" involves continuous cultivation, with the consecutive planting of two or more crops per year, and requires a tailored program of fertilizer application to the acidic and nutrient-deficient soils. My analysis of the program indicates that previous assessments of its long-term sustainability and profitability were overoptimistic, and its proposed effect of reducing deforestation is questionable. Governments should not count on the Yurimaguas technology for an agricultural bonanza in Amazonia.

The "Yurimaguas technology" (Nicholaides et al. 1983a,b, Sánchez et al. 1982; see also Sánchez 1977, Sánchez and Benites 1983, Valverde and Bandy 1982) refers to planting two to three crops per year as continuous rotations of either upland rice/ maize/soybeans or upland rice/peanuts/soybeans (Sánchez et al. 1982). A variation, called the improved Yurimaguas technology, has rotations of maize/peanuts/maize; peanuts/rice/soybeans; or soybeans/rice/soybeans (Nicholaides et al. 1985). Not all of the problems affecting the Yurimaguas technology apply to the several other agricultural systems under testing at the Yurimaguas station.

The Yurimaguas technology was developed by agronomists from North Carolina State University (NCSU) and Peru's National Institute for Agricultural Research and Promotion (INIPA) to demonstrate continuous cultivation in the Amazonian uplands. The system's developers (Sánchez et al. 1982, p. 825) state "The continuous production system is economically viable over a wide range of crop and fertilizer prices, capital levels and labor force compositions."

Soil fertility maintenance

Continuous cultivation cannot survive in Amazonia if successive agronomic problems introduce costs that prevent the strategy from being competitive with production elsewhere and with other alternatives within Amazonia. Over time, soil depletion, for example, becomes increasingly expensive and difficult to correct. The cost of replacing all the nutrients removed in the harvested crops or lost through such processes as erosion, leaching must include not only the purchase and transport of fertilizers, but also the expense of identifying for each field, and informing the farmer, which elements are deficient in what amounts. The principal macronutrients (nitrogen, phosphorus and potassium), together with lime, account for most of the expense of purchase and transport. Sánchez et al. (1982) state that the quantities of fertilizer needed to supply these elements are similar to those used by farmers in the southern United States. Although this seems to imply that agriculture could be as profitable in the Amazon as in the Carolinas, the long transport distances make fertilizer cost much higher and the prices received for the crops much lower in Amazonia. The substantial areas of abandoned farmland in the southeastern United States reflect the power of soil depletion even under economic conditions that are more favorable than those in Amazonia for intensive use of fertilizers.

Although correction of micronutrient depletion requires only small amounts of fertilizer, micronutrient deficiencies add substantially to the farmers' cost and risk. Nutrients must be balanced to avoid detrimental synergisms. In the Yurimaguas technology, soil samples are analyzed after each crop in order to calculate the proper nutrient mix for fertilization.[1] Separate information is needed for each field in order to make the system work. Sánchez et al. (1982, p. 824) state that "the timing of the appearance of soil fertility limitations and the intensity of their expression varied among the (three test) fields, even though they were near each other, were on the same soil mapping unit, and had the same vegetation before clearing."

An awesome expansion of laboratory and extension services would be necessary if the Yurimaguas technology were widely implemented. While these services have been provided free of charge (i.e., as a subsidy) by NCSU for the farmers collaborating with the Yurimaguas experiment station, either the farmers, taxpayers or consumers in the Amazonian countries would have to bear these expenses in an expanded system.

The capital required to assure adequate fertilizer application is more than all but a few Amazonian farmers have. Not only must the requisite doses be purchased and applied for each crop, but the farmer must be capable of making the outlay a second time should an application be lost to heavy rains. Torrential rainstorms that can sometimes drop several hundred millimeters of precipitation in a 24-hour period occur every few years in Amazonia. This happened in Yurimaguas in 1975, washing away an application of lime and lowering yields (NCSU Soil Science Department 1975). In 1983 a similar event eliminated recently applied nitrogen. In both cases the experiment station was able to obtain and reapply the chemical inputs (Weischet 1986).

When the Yurimaguas results were obtained (Sánchez et al. 1982; see also Nicholaides et al. 1985), the eight-year-old experimental plots required--in addition to nitrogen, phosphorus and potassium--replacement of five other nutrients: magnesium, copper, zinc, boron and molybdenum. Three years later, two more nutrients were deficient: sulfur and manganese.[2] The research group complains about the difficulty of obtaining adequate purity in the soil samples and sufficient precision in the laboratory analyses: with micronutrients, a difference of only a few parts per million can have a large impact on crop yields. The difficulty of obtaining such precision would be much greater for farmers handicapped by geographical isolation, little education, and a tenuous link to laboratory facilities through a chain of often poorly trained and poorly motivated extension personnel.

The Yurimaguas authors admit: "In the complete treatment, fertilizers and lime were added according to recommendations based on soil analysis. During the second or third year, however, yields began to decline rapidly. Soil analysis identified two possible factors ... lime and ... magnesium." (Sánchez et al. 1982, p. 824). If yields can suffer from misassessment of nutrient needs in an experimental plot closely monitored by a highly-qualified team of research agronomists, such declines would be much more frequent in the fields of Amazonian farmers--particularly the "shifting cultivators" identified as the system's intended beneficiaries.

Erosion

Erosion also impedes widespread use of the Yurimaguas technology. The Yurimaguas experiment station is almost totally flat, but signs of erosion are apparent at Yurimaguas wherever slight slopes occur. Only a small portion of Amazonia is flat at a scale of a few tens of meters. Sá ánchez et al. (1982) indicate that 50% of the Amazon region is well drained and has slopes less than 8%, the maximum slope the group suggests for the system. The survey on which the information is based (Cochrane and Sá ánchez 1982) used the side-looking airborne radar (SLAR) imagery of the RADAM Project (Brazil, Ministério das Minas e Energia, Departamento Nacional de Produção Mineral, Projeto RADAMBRASIL 1973-1982) mapped at a scale of 1:1,000,000. When specific localities are examined that are within the less-than-eight-percent slope areas, much of the land is found to have steeper slopes. In a 23,600 ha area on Brazil's Transamazon Highway shown by Cochrane and Sánchez (1982) as all having less than 8% slope, a map of 1180 20-ha quadrats based on measurements at 225 locations showed 49.3% of the land to have slopes at least 10%, and some to have slopes as high as 89% (Fearnside 1984, 1986).

According to Sánchez et al. (1982, p. 822), "Only about six percent of the Amazon has soils with no major limitations to agriculture. Nevertheless they represent a total of 32 million hectares. They are classified mainly as Alfisols, Mollisols, Vertisols, and well-drained alluvial soils, and where they occur permanent agriculture has a good chance of success". Alfisols and Vertisols, which are among the more fertile soils, normally occur on more steeply sloping terrain than do the less fertile soil types (Falesi 1972, Fearnside 1984). In selecting sites for continuous cultivation in the Amazonian uplands, a tradeoff will be faced between soil fertility and suitable topography. In Brazil there has been a tendency to resolve this kind of tradeoff by ignoring long-term restrictions from unfavorable topography in order to exploit higher-fertility soils. The choice of sloping Alfisols for siting the sugarcane production area of the Transamazon Highway (Smith 1981, 1982) and the *Gmelina* plantations at Jari (Fearnside and Rankin 1985) illustrate this tendency. The same temptation will apply to the Yurimaguas technology.

Crop pests and weeds

The number and severity of pest and disease organisms generally increase formidably as the cultivated area expands.[3] Using pesticides to counter such problems is expensive. In addition, insects typically develop resistance to pesticides, leading to escalating dosages and costs.[4] Heavy insecticide dosages are already being applied at Yurimaguas. Tropical agriculture generally is plagued by higher insect populations than is agriculture in temperate locations because no winter ever reduces insect populations (Janzen 1970, 1973).

Weed populations are already a major problem. Some weeds, such as the grass *Rottboelia exaltada* in upland rice fields, have not been controlled with herbicide spraying.[5] Intensive hand labor is used to control this weed at Yurimaguas--otherwise it takes over the rice fields and seriously reduces yields. Herbicides, like the other agricultural chemicals required by the system, must be available at critical times. The herbicide preferred at Yurimaguas for rice weeds (other than *Rottboelia*) is metolachlor (tradename, Dual) which had been unavailable commercially in Peru for at least four months as of June 1985. While the experiment station has an adequate stockpile of this and other chemicals, irregular market availabilities of inputs would be a serious impediment for Amazonian farmers.

Economic Problems

The preliminary results at Yurimaguas are poor indicators of the system's performance under more representative circumstances. In addition to subsidizing extension and soil analyses, NCSU and the Peruvian government underwrite the true costs in a number of indirect ways. Fifty percent of the cost of transportation for fertilizer is provided by the Peruvian government, lowering the Lima-to-Yurimaguas rate to US$1.20/kg. A special agreement between the experiment station and the Peruvian Air Force provides free transportation for many lighter items and for items needed when roads are impassable during the rainiest months. Transportation to and from the Yurimaguas area is also subsidized through government price supports. Fertilizers available in commercial outlets in the town of Yurimaguas are sold at essentially the same prices as those in Lima, even though phosphates, potassium and nitrogen fertilizers come to Yurimaguas from the coast. Lime, fortunately, is available from limestone outcrops along the Upper Huallaga River, to which the Yurimaguas River is an affluent. The government buys products such as rice at the same fixed prices whether in Amazonian locations or in the irrigated rice areas along the northern part of Peru's Pacific coast with paved highways to the major consumer markets. Thus, in effect, the costs of transporting Yurimaguas rice to market are being paid by urban consumers, taxpayers and Peru's international creditors. The cost of providing these subsidies to the increased number of farmers if the Yurimaguas technology became widespread in Amazonia would be prohibitive to any of the financially pressed governments of the Amazonian countries.

The collaborating farmers at Yurimaguas have received many free inputs from the experiment station, including seeds, fertilizers, lime, pesticides, and herbicides. In addition, the roughly 25% of the participating farmers who live along a road near the experiment station have received an important subsidy in the form of the station's agricultural machinery. The farmers pay rent for the machinery use, but rental equipment would be more expensive elsewhere. The farmers would need to assume the debt service costs for the capital necessary to buy tractors and other equipment used only during a small portion of the agricultural year. Farmers would also have to maintain the equipment--an extremely expensive enterprise in the Amazon. Not only does machinery deteriorate more quickly than in temperate zones, but parts and the services of skilled mechanics are much less readily obtainable.

Those collaborating farmers in locations too isolated to have access to tractors have been subsidized more directly. Digging and turning the soil using hand tools is a particularly onerous task as the soil becomes progressively more compacted under continuous cultivation. The amount of labor required became prohibitive in the absence of tractors, and NCSU paid outside laborers to go to the more remote properties and turn the soil for the collaborating farmers. The Yurimaguas technology is unlikely to spread if the work of turning the soil by hand is too heavy for the collaborating farmers to do themselves and too expensive for the agricultural production to justify their paying others to do.

Subsidies are only one reason that the interpretation the Yurimaguas authors give to their results is probably overoptimistic. The farmers participating in the Yurimaguas trials are not typical of the rural Amazonian population. Nicholaides et al. (1984) leave no doubt that these model farmers, described as "respected community leaders" (Nicholaides et al. 1985), are some of the best in the Yurimaguas area. Certainly the farmers who have volunteered to collaborate with the experiment station are a select set who have more money, initiative, and contact with urban society than the "shifting cultivators" indicated by Sánchez et al. (1982) as the target population for the Yurimaguas technology.

The agricultural extension portion of the program is also atypical of Amazonian conditions. It has trained a team of local extension agents, who have not yet been entrusted with the task of serving as intermediaries between the station and the collaborating farmers. Even such fundamental concepts as the difference between linear and square measures are not easily grasped by the local extension agents. The head of the experiment station's extension sector has therefore retained personal responsibility for communicating with the collaborating farmers. Only the small number of farmers allows such a highly qualified person to advise them directly.

The results presented in 1982 were overoptimistic because the collaborating farmer program had been underway onlt three years (Sánchez et al. 1982), and only two years of production data were available. Even with traditional methods, yields in tropical farmers' fields are usually reasonably high in the first two years after clearing, only thereafter declining rapidly (Nye and Greenland 1960). The early results presented for collaborating farmers are therefore a poor indicator of long©term sustainability. Heavy fertilization, of course, allowed much higher yields and more crops per year than would otherwise have been possible in the first two years. The claim that "the first eight farmers averaged 3 tons of rice per hectare, 4.5 tons of corn, 2.6 tons of soybeans and 1.8 tons of peanuts--similar yields to those obtained at the station" (Sánchez et al. 1982, p. 825) does not demonstrate that high yields will be maintained in the collaborating farmer plots over the nine-year period the experiment station plots had run at that time, much less over the long term.

The most telling evidence that the "technology validation in farmer fields" (Sánchez et al. 1982) was premature in claiming commercial success is the later history of the program. In 1982 the Yurimaguas researchers were able to state that "the tests have expanded, and farmers are attracted by the prospects of increasing their yields" (Sánchez et al. 1982, p. 825). The picture has changed markedly in the years since. In 1985, according to researchers at the experiment station, no farmers in the Yurimaguas area were employing the Yurimaguas technology of high-input continuous cultivation on a commercial basis. Even the farmers in the special program, with inputs given or subsidized by NCSU, had switched to lower-input options introduced under the program. The Yurimaguas researchers' calculation that the system would be highly profitable using input and product prices prevailing in Yurimaguas (i.e., without direct subsidies, but still including the indirect ones through price supports, free extension, etc.) is contradicted by this lack of response on the part of the area's farmers.

Limits to the technology

Large-scale expansion of the Yurimaguas technology is likely to encounter limits. One is the inherent difference in production efficiency between upland and irrigated rice. Irrigated rice plantations in Peru's coastal lowlands, for example, apparently can produce this cereal more cheaply than can upland farming in the Amazon. Another constraint to high-input agriculture is the availability of phosphate rock. Amazonia has virtually no phosphate rock (de Lima 1976, Fenster and León 1979). Brazil's major phosphate deposits are in the south central state of Minas Gerais, and Peru's are in the Pacific coast state of Piura. On a global scale, most of the world's phosphates are located in Africa (Sheldon 1982). The earth's phosphate deposits are finite, and use has been increasing exponentially since the end of World War II (Smith et al. 1972, United States, Council of Environmental Quality and Department of State 1980). As phosphate supplies dwindle in Amazonian countries and in the world, the price of this input can be expected to increase dramatically, shifting the economic balance even further away from high-input systems like the Yurimaguas technology.

Policy implications

The Yurimaguas technology was presented as a practical means of combatting deforestation. The systems developers imply that Amazonia's high deforestation rates are caused by shifting cultivators clearing land in order to grow food for their subsistence needs: "We believe that the continuous cropping technology can have a positive ecological impact where it is practiced appropriately, because for every hectare that is cleared and put into such production, many hectares of forest may be spared from the shifting cultivator's ax in his search to grow the same amount of food. People do not cut tropical rainforests because they like to, but because they need food or fiber" (Sánchez et al. 1982, p. 827; see also Nicholaides et al. 1985).

This view of the deforestation problem is incorrect. Especially in Brazil, large ranching operations account for most deforestation (Fearnside 1983). Even in parts of Amazonia where small farmers are of greater relative importance, the farmers do not fit the mold of traditional subsistence farmers who limit the areas they cultivate once the production satisfies the nutritional needs of themselves and their families, plus a margin to protect against shortfalls in lean years. Brazilian colonists in government settlement programs, for example, have a virtually insatiable demand for goods: the areas cleared and planted are limited not by humble ambitions but rather by the amount of labor and capital available to the farmers for expanding their agricultural activities (Fearnside 1980). Increasing yields would have little negative effect on clearing rates. Profits from the intensive farming would probably be invested in rapid deforestation for extensive land uses such as cattle pasture.

This scenario has often been the response of beneficiaries of another cropping system promoted as an antidote to deforestation: cacao. In Rondônia, Brazil, cacao planters who have ready cash from a good cacao harvest frequently invest these profits in cattle--an understandable strategy to insure against low cacao prices or increased losses of cacao to fungal diseases. Similarly, should farmers find the Yurimaguas technology profitable, the earnings might well be invested in deforestation for cattle pasture.

This is not to imply that farmers should be kept poor to avoid deforestation. In considering the pros and cons of the Yurimaguas technology, however, impact on deforestation is likely to be a con rather than a pro. A correct understanding of the deforestation process is essential both to formulating effective policies to slow clearing and to developing sustainable land uses.

The illusion that new technologies are about to transform Amazonia into an agricultural breadbasket is inherently alluring to government planners, who have in the past often promoted the region as an El Dorado that will someday solve national problems of every description. The El Dorado myth diminishes planners' incentive to find solutions to such problems as the underlying causes of the rapid spread of cattle pasture in Amazonia today and the land tenure concentration and population growth in the non-Amazonian areas from which a rising flood of migrants is being expelled.

The Yurimaguas technology points to a persistent dilemma in the search for ways to improve Amazonian agricultural systems. Research and extension efforts to improve agricultural technology are vitally important for the future of the area. At the same time, their development must not be presented in a way that feeds false hopes of an agricultural bonanza in Amazonia capable of freeing national policymakers from facing the politically riskier issues of population growth and resource concentration.

Notes

1.) Soil analyses and fertilizer dosage adjustments after every crop in the "technology validation in farmer fields" described by Sánchez et al. (1982) strongly suggest that this frequency of sampling is integral to commercial application of the Yurimaguas technology. Elsewhere in the Peruvian Amazon a commercial system with only one sample per year for every five to ten hectares is reported to be successful so far (J.H. Villachica, personal communication, 1985, INIPA, Iquitos). Reduction of the sampling rate is a logical cost-reducing step, but would probably result in lower yields than those reported for the Yurimaguas technology.

2.) D.E. Bandy, personal communication, 1985, NCSU/INIPA, Lima.

3.) This pattern accords with the theoretial expectations of MacArthur and Wilson (1967); for an example with sugarcane, see Strong et al. (1977).

4.) For an example from coastal Peru see Barducci (1972).

5.) J. Mt. Pleasant, personal communication, 1985, NCSU/INIPA, Yurimaguas.

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