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SOME ENVIRONMENTAL AND HEALTH ASPECTS OF AGRICULTURAL SETTLEMENT IN THE WESTERN AMAZON BASIN

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INTRODUCTION

The eyes of the environmentally conscious are more focused than ever on the Amazon Basin. This is particularly true of the western Amazon, where a series of colonization projects, gold discoveries, random settlements, and mammoth infrastructural development schemes have promoted almost uncharted (and perhaps uncontrollable) economic growth and devastation in one of the world's most fragile natural resource bases. International concerns have risen and national tempers have flared as governments and special interest groups have grappled with the methods (and wisdom) of exploiting the Amazon Basin as an integral part of national development strategies.

At the same time, the eyes of the socially conscious are also focused on the Amazon Basin. Tropical disease and malnutrition continue to take heavy tolls on resident populations, and the lack of primary education and other social services have frustrated colonists' dreams of a better life. Children born and raised in some colonization projects face every possible obstacle in their physical

and mental development; indeed, those who reach age 5 are sometimes referred to as "heroes."[1]

Attempts to meet household food needs increase the pressure on the natural resource base, and it is here, in the area of nutrition and food production, that the concerns of the environmentally and socially conscious converge. On the one hand, the environmentally conscious worry about the vast amounts of deforestation in the western Amazon partially caused by food production. On the other, the socially conscious realize that, due to limited and seasonally variable links to markets, small-scale, self-sufficient farming (in spite of its negative impact on the environment) is the only way to insure adequate household nutrition. Current debates regarding the focus and amounts of private and public investments in these areas suggest that inadequate infrastructure will continue to characterize the region, and this scenario of degradation will persist. If this is true, then the "food production - environmental degradation" nexus needs to be better understood, and policies aimed at mitigating environmental damage while providing adequate nutrition and health to inhabitants of the Amazon Basin must be devised.

Our purpose in this paper is to provide a sketch of the "food production - environmental degradation" nexus at two points along a stylized agricultural development path in the Amazon Basin, sensitize our readers to the often misunderstood and/or overly discounted

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[1] Conversation with John Syndenstricker regarding 1986 field research in Machadinho.

effects of the natural environment on the human population, and finally suggest a research agenda and scope for policy. One section is dedicated to each objective.

The data and intuition supporting this paper are drawn from two on-going studies in the western Amazon Basin. The first is a micro-level study of the Machadinho Colonization Project in Rondonia, Brazil. The second is a region-wide study of the Selva Baja in Peru. Study-specific inferences are highlighted where appropriate.

Part 1 -- Links Between Agricultural Production and the Environment

A first step in understanding the links between agricultural production and environmental degradation is to examine incentives (and disincentives) and constraints that jointly determine land-use patterns in this ecologically fragile region. Land-use decisions reflect farmer management of a set of production factors (land, labor, capital and technology) in response to available information on agroecological conditions, market opportunities and household demands. Farmer management can be seen as an adaptive strategy, a set of coping behaviors in the face of often changing environmental conditions (Bennett 1976). Adaptive strategies pursued at the individual or group level often have an impact on the prevailing ecological conditions (natural resources such as soil, water, vegetation, incidence of disease, etc.), and market conditions that in turn require adjustments in the farmer's adaptive strategies. This dynamic

relationship between adaptive strategies and environmental conditions has been termed the adaptive process by Bennett (1976).

1.1 Initial Land Clearing

Newly arriving migrants face severe capital and labor constraints, an often complete absence of logistical and technical assistance, and a general ignorance of the inherent potential of the abundant (though poor quality) land at their disposal. Farm households, which are generally fragmented during the initial colonization process, commonly arrive with sufficient stores of food and liquid assets to survive approximately 6 months -- somewhat less time than is required to harvest the first annual crop, and years before any perennial tree crops will bear fruit. This set of circumstances leads to the immediate and rational decision to deforest as much land as possible during the first drying season, a process that logically continues up to the point where human resources are exhausted or the drying season begins, whichever comes first. (Clearing land for the purposes of food production was a key component in the deforestation of over 11% of the total area of the State of Rondonia, by 1985 [Malingreau and Tucker, 1988].) Once dried, the forest is burned - logically - since in most cases the residual ash is the only fertility-increasing additive (natural or otherwise) the Amazon soils are ever likely to receive.

Once the land is cleared and burned, the first phase of ecological degradation is complete -- the forest is gone. If

abandoned, something will grow up in its place, but except in special cases the complex ecology of the climax forest will not be regenerated. From the point of view of farm households arriving to these areas, the decision to deforest is necessary for survival, and rational. Indeed, no viable economic alternative exists for the vast majority of participants in the colonization process.

1.2 Land-Use Decisions

The second phase of ecological degradation begins with longer term land-use decisions. In general, colonists continue to be capital and labor constrained, but, unlike in many areas in Latin America, most peasant-farmers in the Amazon have abundant (low quality) land. Unless long-term strategies are sustainable, farmers will be driven to clear new land for their families' survival.

By and large, initial crop planting decisions are dominated by food consumption habits and the knowledge that properly functioning, continuously linked (especially seasonally) regional markets are lacking. Annual crops of rice, beans and corn occupy a majority of cleared land during the first 2 crop cycles, with a substantial portion of the remainder dedicated to manioc -- the "last resort" crop with an important social function but, unfortunately, low in nutritive value.

The rapid decline in soil fertilities associated with the production of annual food crops prompts major changes in land-use strategies. These new strategies vary from extensive planting of

perennial tree crops to beef cattle production, and choices depend (overwhelmingly) on the input and output marketing mechanisms and policies supporting these options. In what follows, we focus on the small-to-medium scale incorporation of beef and dairy cattle into farming systems in the humid tropics. This is portrayed as a logical extension of the initial slash and burn phase - a situation which, in the Peruvian case at least, holds true.

One common strategy among colonists responding to rapid declines in yields of annual crops is to take that land and convert it to pasture, while continuing to slash and burn new (relatively fertile) land (as available) for annual crops. The latter provide a short-run return through the harvest and sale of crops, as well as guaranteeing a food and seed supply for the coming year. The sown pasture serves a double function -- it provides forage for cattle (if any are present), and also provides physical proof of land occupancy in an environment where legal titles are rare and land disputes frequent. It may also provide a source of income if the pasture is rented to neighbors. Therefore, pasture is a valued good in its own right, independent of cattle ownership.

Cattle raising has been roundly criticized as damaging ecologically (Goodland, 1980) and even antieconomical (Mahar, 1988; Hecht, Norgaard, and Possio, 1987).[2] Though subsidy-driven extensive cattle ranching by large landowners has received the most attention

[2] Recent evidence collected by Monte Mar in the Eastern Amazon however suggests that large-scale cattle ranching may be very profitable indeed (personal communication).

and criticism (Hecht, 1982; Mahar, 1988), raising cattle also characterizes the adaptive strategies of small-to-medium landholders. This presents us with a puzzle: if cattle raising is an ecologically nonsustainable and unprofitable land use, in both the short and long run, why is it so widespread?

Although standard economic analyses may indicate that cattle are not profitable (due to low rates of weight gain), for the Amazonian colonist they fulfill multiple objectives within the farmer's strategy of securing adequate income and food production. Farmers are interested in acquiring and maintaining a herd of cattle for its value as a capital good; the animals represent a store of wealth, especially in highly inflationary economies. Cattle are also a readily-marketed high-value good. At the same time, cattle raising is relatively undemanding in terms of labor, which is critically important to the labor-constrained household economy. In frontier situations where infrastructure and marketing channels are precarious, cattle's marketability and ability to "walk to market" makes it an attractive alternative. And, if there is a nearby urban center (as is increasingly the case in the rapidly urbanizing Amazon), the farmer may be able to market small quantities of milk, providing a daily -- and much appreciated -- cash flow. If no urban center is nearby, the milk may be converted to cheese and sold or consumed by the family.

But is cattle raising an ecologically unsound land use in Amazonia? The Amazon, in particular the "terra firme" uplands, are characterized by highly acidic, infertile soils. This difficulty is

compounded by intense soil disease pressure and unrelenting weed growth. Pastures, while better adapted to these conditions than many crops, usually degrade over time with declining soil fertility and increasing weed pressure (see Figure 1). Figure 1 illustrates the impact of mixed crop-livestock systems on soils in the Amazon Basin. The low inherent natural fertility of many of these soils is raised dramatically by cutting and burning the forest. The nutrients added to the soil quickly begin to decline due to leaching and other processes. Pastures are planted on soils that have already suffered some decline in fertility from the adequate levels provided by burning. Over time (3-5 years) nutrients in the soil continue to decline under pasture, until the land is degraded, i.e. nutrient levels fall below even the low natural fertility under forest.

Loss of soil fertility is exacerbated by two other factors associated with the use of the land as pasture: physical damage to the soil (compaction) caused by grazing animals, and suppression of successional vegetation caused by farmers' efforts to combat weed growth. Compaction, elimination of pioneer arboreal vegetation, and declining levels of fertility combine to suppress the process of revegetation delaying the natural soil recovery upon which successful slash and burn farming depends. As Uhl, Buschbacher and Serrão (in press) point out, abandoned pastures take longer for the re-establishment of forest cover than abandoned swidden plots subject only to annual cropping. This pattern was observed in the Peruvian Amazon where bush fallows following pasture took twice as long to

accumulate a given level of biomass compared to fields abandoned after annual cropping (Loker 1989). Thus, while cattle raising provides an important source of security and income in the uncertain world of farming in the Amazon, it does lead to land degradation, undermining the sustainability of the farming system.

It should be clear by now that food production plays a critical role in all phases of environmental degradation. It is a major rationale for initial deforestation and subsequent land use in situations characterized by undependable markets for agricultural products and inputs in partially-monetized economies. When combined with decreasing soil fertility levels, this situation leads inevitably to continued forest clearing.

Part 2 -- The Impact of the Environment on Settlers' Welfare

While there is a resounding international outcry associated with the impact of agriculture on the natural environment in the Amazon region, relatively little attention is paid to the impact of the environment on settlers' welfare. Although environmentally-induced decreases in settlers' welfare might be seen as yet another argument for halting (or even reversing) the settlement process in the western Amazon, policymakers and researchers must become sensitive to the fact that hundreds of thousands of people were drawn to these areas and are unlikely to return to their places of origin (even in the medium- to long-run), and concern for their well-being must rank at least as high on our priority list as concern for the fragile lands they occupy.

There are two major shocks dealt to settlers by the environment, both of which are theoretically amenable to policy intervention, but in practice represent potentially devastating blows that must be coped with at the household level. The first shock is linked to the dramatic climate-induced seasonal swings that affect virtually every facet of life and dramatically reduce economic and agricultural options open to settlers at certain times of the year. The second, and perhaps most profound, shock comes in the form of rapid deterioration of health brought on (primarily, but not exclusively) by tropical disease.

Perhaps one of the most severe climatically-induced shocks is the marked seasonality that most settlers encounter, and that physical and social infrastructure are ill-prepared to mitigate. In the Machadinho Project site, for example, the rainy season lasts on average 3½-4 months, during which time bridges and roads are often impassible and markets for inputs and outputs (especially food) function only sporadically. Employment opportunities disappear, and farm-households (most notably recent arrivals) are forced to devise alternative coping strategies with little government or community support.

Perhaps the sharpest decline in human welfare associated with the environment of the Western Amazon is found in the area of human health. Malaria prevalence rates were (and in many cases still are) very high in most colonization projects, almost regardless of their respective states of development. The costs associated with the disease seem to vary inversely with the degree of development - being

highest during the early stages of colonization when human labor (especially adult male labor) is dear and community-based support is minimal, and lower as market integration (especially wage labor) becomes more complete. In addition, field research suggests that poor health and disease initiate a downward spiral of "decapitalization" as treatment costs outpace income and begin to erode the scant liquid and illiquid assets available to rural households. This downward spiral is hypothesized to be responsible for a significant proportion of land abandonment as poor, malaria-stricken households mortgage their possessions (including land) to pay for health care, and depart the sites when the remaining equity approaches the value of bus fare to the nearest town or next project site.

Finally, sanitation is abysmal (especially, and perhaps ironically, in some of the relatively "urban" areas), and education (if it exists at all) is of very poor quality. Poor sanitation and education are due, in part, to insufficient public and private investment, but also reflect the higher costs of making lasting investments in, and attracting qualified personnel to, these remote and inhospitable areas.

Part 3 -- Potential for Sustainable Agricultural Development in the Humid Tropics

3.1 Induced Unstable Equilibria

Before moving on to suggest research agenda and discuss the scope for agricultural and other policies, it might be instructive to review

the set of circumstances that gave rise to settlement in the western Amazon (particularly the case of Brazil) to highlight the uniqueness and instability of the current situation, and to call for quick action on the part of policymakers.

It is well known that, at least in the Brazilian case, the vast majority of agricultural expansion in the Amazon Basin was due (directly and indirectly) to policy incentives provided by the federal government seeking to settle the "frontier" for a number of reasons (see Mahar, 1988). It is also common knowledge that the policy package that stimulated the settlement process is not politically or economically sustainable, and that the tendency is to fiscally "wean" hinterland areas and allow market forces to dictate the direction and pace of future development. This trend has several possible outcomes. On one extreme (once again in the Brazilian case), the frontier area could derive its own comparative advantage and become completely frontier area linked with other domestic markets. On the other extreme, high transportation costs associated with large distances and decaying physical infrastructure could nullify any major economic advantages the region might enjoy and dictate a situation close to autarchy. This scenario would severely limit strategies open to settlers, with grave consequences in both the social and environmental spheres.

Regardless of where the Amazon Basin's agricultural communities end up on this economic integration spectrum, it is clear that these areas were "conceived" under highly skewed and artificial economic

circumstances and that their continued existence (and welfare) depends (in part) on the generation and diffusion of appropriate small-scale agricultural technologies, and the derivation and implementation of policies that are consistent across regions, and over time.

3.2 New Lands, New Farmers, New Needs

The Kuznetsian approach we have adopted (for explanatory purposes) in treating two areas of different levels of development as distinct points along a common development path is not strictly correct. The Amazon Basin is a collection of very different micro-environments with differing links to national and international markets, and subject to the laws and policies of different governments. Factor endowments also vary dramatically over relatively small geographic areas. All of this suggests that common solutions do not exist - either across regions or over time.

The Amazon Basin is a poorly understood environment (a "knowledge frontier" c.f. Moran 1980) -- both by the colonists who seek their fortune there and governments who formulate policies for its occupation. Colonists come to the region with traditions and agronomic practices shaped in distinct agroecological conditions (the Andean highlands, diverse areas in Brazil) that are often inappropriate to their new circumstances. High failure rates in many colonization schemes reflect this inexperience. Those who have acquired agronomic skills and techniques appropriate to the region's ecology (at least in the quasi-autarchic state prior to settlement)--

native peoples and long-term forest dwellers -- far from being consulted and incorporated into the development process, are actively ignored or displaced by most colonization schemes. Those directly responsible for providing sound agronomic advice to colonists -- the national agricultural research and extension systems -- are either conspicuously absent or lack sound recommendations to aid new arrivals.

The agronomic difficulties associated with farming the Amazon (predominance of low fertility, fragile soils, high biotic and abiotic stresses for crops, etc.) are compounded by the region's isolation from any major population area -- which translates into distant markets for both products and needed inputs. Colonization of the region has only been made possible by massive investments in "hard infrastructure," particularly roads, often unaccompanied by adequate investments in "soft infrastructure, " such as schools, medical facilities and agricultural research facilities essential to settler welfare.

3.3 Research Responses and Policy Intervention

If we assume that a viable small-to-medium farm sector in the Amazon is a desirable goal, the solution to the problem of agriculturally-induced land degradation requires a two-pronged approach: we need technology to solve the degradation problem and policies that address the unbalanced factor proportions that encourage extensive land use. Technology research needs to focus on the short-

term goal of correcting inappropriate land-use practices and generating quickly and widely available "intermediate technologies" that reduce land degradation associated with current land use systems. Any technological solution, to be compatible with the farmer's principal constraints and adaptive strategies, must maximize return to labor and minimize capital inputs. It also must address the farmer's need for diverse sources of income as a buffer against crop failure or price declines in any one component of the farming system. Until an adequate substitute for cattle is found, that fills the same functional role in the farming system, farmers will continue to plant pastures and try to acquire cattle as an important element in their immediate survival strategies -- to the detriment of the sustainability of the farm enterprise and the Amazonian ecosystem.

Most technological solutions offered to date have focused on permanent or tree crops, as a potential longer-term strategy due to their ability to provide constant soil cover (avoiding loss of soil nutrients). However, many tree crops suffer from severe marketing constraints, with widely fluctuating prices (coffee, cacao), lack of established markets (achiote and native fruits such as camu-camu or pejibaye), or perishable products (citrus and other fruits). Often there is a considerable delay between investment in planting and anticipated profits, an intolerable situation for the capital-short (due to lack of accumulated wealth and agricultural credit) Amazonian colonist.

Longer-term research needs first to identify, then overcome the natural constraints to agricultural production by generating ecologically sensitive technologies. At present the Amazon Basin, due to the natural difficulties to successful farming, severely compounded by inadequate links to distant markets, is a region in search of a comparative advantage. Research can perhaps relax some of the natural constraints to agricultural production, raise labor productivity and lower the costs of production to make the Amazon competitive in some agricultural products in the long run.

However, given the time lags associated with the generation and diffusion of new agricultural technologies and the urgency of the environmental problems in the region, policy reforms or innovations may be the most effective short-term instrument for correcting damaging land-use practices. New approaches for zoning, tax policies and selected use of subsidies to encourage less damaging forms of land use may do more to reduce environmental degradation, ease social conflicts and promote settler welfare than any agricultural technologies either on the shelf or in the research pipeline. There is an urgent need to reduce environmental degradation to avoid foreclosing future options for Amazonian development. It is a much more feasible challenge to determine appropriate productive uses for intact ecosystems, than bear the social and economic costs of restoring degraded ecosystems.

Regardless of future decisions on further frontier expansion, the Amazon Basin now holds about 20 million people engaged in a variety of

activities from gold mining to coca growing, from cattle ranching to irrigated rice production. If the frontier begins to close there will be a need for viable agricultural systems to provide adequate incomes, food supplies, and an economic surplus for the region. Continued research into appropriate agricultural innovations for sustainable production systems under the ecosystemic conditions in the Amazon will be a necessary component in any strategy to better utilize already cleared lands and avoid further destruction of intact ecosystems. Technology research must be accompanied by research into the appropriate policy environment to encourage appropriate forms of land use and encourage adoption of improved technologies as these become available. A combination of improved agricultural technologies and policies to support them may avoid the destruction of the ecological and cultural heritage of the Amazon.

Finally, the critical links between food production, infrastructure and human welfare in the Amazon Basin cannot be over-emphasized. Insufficient infrastructure leads to costly and often (seasonally) non-existent market links that promote overreliance on traditional small-scale agricultural self-sufficiency and highly detrimental land-use patterns. Large and concentrated investments in physical and social infrastructure will be required to expand market options (including those for modern agricultural inputs) and accelerate (artificially, to a certain extent) the process of economic and geographic consolidation to break the cycle of environmental degradation caused by small-scale, low-input agriculture.

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Figure 1

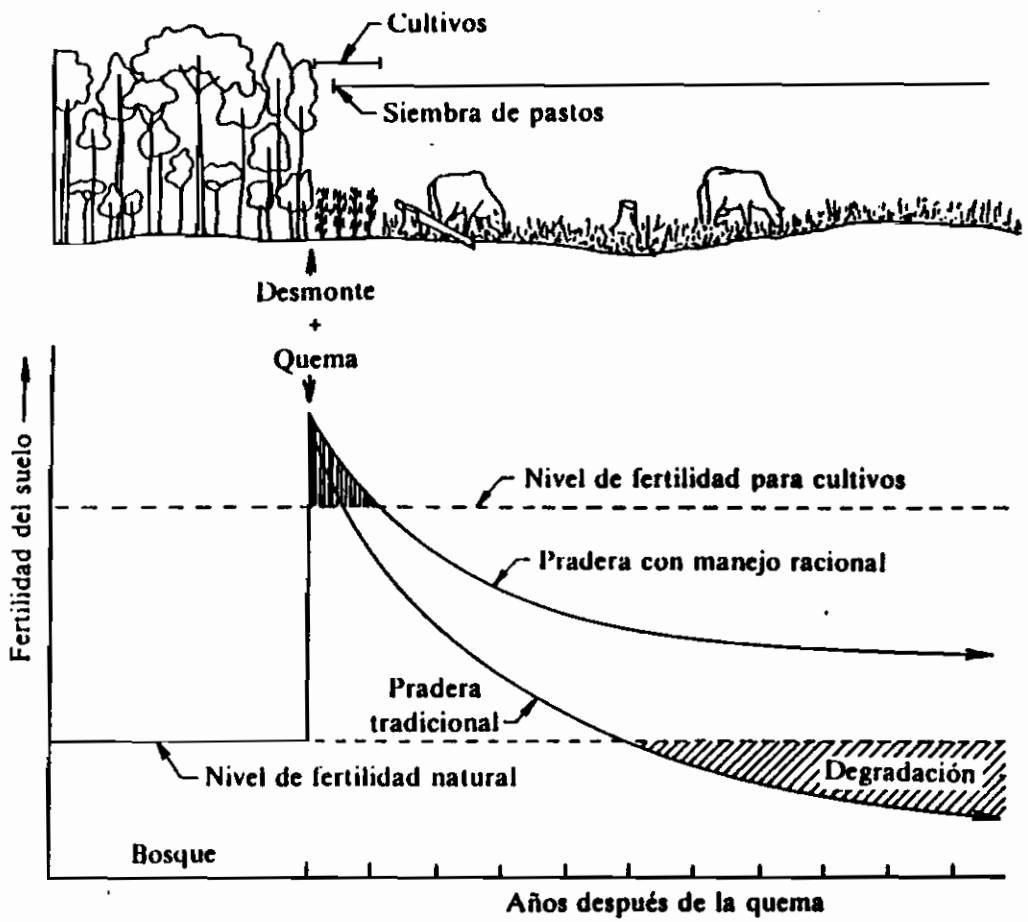

Figura 3. *Modelo que muestra los cambios probables de fertilidad del suelo al cambiar de la vegetación de bosque a la de pradera.*

Fuente: Toledo, 1977; Serrao, 1978; Alvim, 1978.

Durante los primeros años después de la tala del bosque, los niveles de manejo se encuentran limitados por la imposibilidad de mecanización, debido a la presencia de residuos del bosque (troncos y tocones) no quemados. Aunque es posible desmontar y limpiar inicialmente el área con buldózer*, esto sería contraproducente debido a la compactación inicial y movimiento de la capa superficial del suelo que contiene la mayor parte de los nutrimentos (Seubert *et al.*, 1977; Ferreira da Silva, 1978).