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Environment, Development and Politics: Capital Accumulation and the Livestock Sector in Eastern Amazonia

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Summary — Deforestation and environmental degradation are increasingly common themes in the literature on humid tropical rural development. This paper explores the frameworks used to analyze environmental questions in developing economies and how well these function in the particular case of livestock development in the Eastern Amazon Basin. The paper argues that, due to the peculiarities of the state subsidies available for ranching activities that spurred a frenzy of land speculation, the exchange rather than productive value of land became paramount. In such a context, cautious land management was irrelevant and serious environmental degradation was the result. The paper suggests that models of environmental degradation that focus only on the question of production cannot capture the environmental dynamics of speculative economies.

1. INTRODUCTION

The Amazon Basin has increasingly become the focus of international attention. As the largest area of remaining tropical rainforest biome, it has a relatively unexplored resource potential, and is regarded as one of the last agricultural frontiers. Recent decades have witnessed the rapid conversion of forest to agricultural landscapes (primarily pasture) in Amazonia, stimulated by a combination of infrastructure development, fiscal incentives and colonization programs. Estimates indicate that about one million hectares are deforested each year (Tardin *et al.*, 1979; OTA, 1983). Unfortunately, much of the area converted to pasture is only ephemerally productive; and a few years after conversion, the productivity of these lands shows a pronounced decline. Estimates of the area of degraded pasture vary from about 20% (Serrao *et al.*, 1979; Toledo and Serrao, 1982), to those, based on LANDSAT data indicating deteriorated pasture levels at closer to 50%, of lands cleared (Tardin *et al.*, 1977; Hecht, 1982; Santos, de Novo and Duarte, 1979).

The conversion of substantial areas of tropical rainforest in Amazonia has been a source of considerable controversy. Biologists voice concern about species extinction (Myers, 1980; Gomez Pompa, Vasques-Yanes and Guevara, 1972; Pires and Prance, 1977), changes in hydrological regimes (Gentry and Lopez Parodi, 1980), local and global climate modification (Salati *et al.*, 1979; Molion, 1975; Salati and Schubart, 1983) and soil resources degradation (Goodland and Irwin, 1975; Goodland, 1980). Social scientists have pointed to the intense land conflicts (Schmink, 1982; Souza-Martins, 1983), increasing peasant marginalization (Wood and Schmink, 1979; Sawyer, 1979; Santos, 1979), extinction of indigenous groups (Davis, 1977) and increased rural-to-urban migration (Martine, 1982; Aragon, 1978; Wood and Wilson, 1983) that have accompanied the process of land development through livestock expansion into the Amazon region.

In contrast to the concerns of biologists and social scientists noted above, Amazonian integration has been described as an essential national development project both in terms of its potential economic and social effects (see, for example, National Development Program — PND II,

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1975; and Alvim, 1978) and the only means of assuring that millions of Brazilians are not condemned to lives of abject poverty. While ecological impacts are acknowledged in this literature, the benefits of development are thought to outweigh the irreversible costs of species lost and Indian extinction. The less catastrophical environmental issues are generally seen as temporary and resolvable. Ecological problems in this view follow a sort of Kuznets curve: as development begins, things deteriorate, but as growth accelerates, technical solutions eventually diminish the deleterious environmental effects.

This paper has several purposes. First, it will briefly evaluate the frameworks used to analyze environmental questions in developing countries, particularly those pertaining to agricultural resources in the humid tropics areas like Amazonia. This will require some discussions of the models themselves. Next, the paper will discuss how environmental questions can be inserted into an analysis of the political economy of Amazonian development, by using an historical and political economy approach to integrate development and environmental issues into one analysis. Through this approach, the dynamics of Amazonian occupation in the 1970s, its associated pattern of capital accumulation and the serious problems of environmental degradation are closely linked. Finally, this paper is a 'middle-level' analysis that focuses on the concrete expression of larger national and international processes as they unfolded and affected the eastern Amazon Basin.

2. MODELS OF ENVIRONMENTAL DEGRADATION

> A model is a metaphor of historical process. It indicates not only significant parts of this process, but the way in which they change. In one sense, history remains irreducible; it remains all that happened. In another sense, history does not become history until there is a model: at the moment at which the most elementary notion of causation, process, or cultural patterning intrudes, then some model is assumed.[1]

The paradigms used for understanding Third World environmental issues are certainly not unique to this particular context; they pervade the environmental literature generally. How the questions are framed, the kinds of data used to support various positions, the level of abstraction and the level of generalization are major problems in environmental analysis. The way ecological problems are theorized in developing countries, however, has simply not received much scrutiny.[2] Further, the conceptions that are used often ignore specific regional histories, their biologies, economies and social dynamics that strongly influence the form and impact of environmental issues.

This section will outline the major environmental frameworks used to understand how Third World environmental questions are posed and developed. These frameworks can be roughly separated into: (1) general biological metaphors; (2) general economic metaphors; (3) at the other end of the spectrum, technology assessment.

(a) *Biological metaphors: Malthus's inexorable population increase*

By far the most prevalent thesis about land degradation in the Third World is the Malthusian view that increasing demographic pressure results in overuse of land and use of marginal land. This kind of cultivation generates soil nutrient decline or erosion with consequent deterioration of the agricultural resource base. In reference to humid tropical areas, the analysis specifically emphasized the problems of slash-and-burn agriculture with population increase (*cf.* Myers, 1980; Sanchez *et al.*, 1982).

The Malthusian framework, currently enjoying a renewed vogue, when invoked as an explanation for Third World poverty, has come under attack from several quarters. This literature is enormous, but representative critics include Durham (1980), Mamdani (1978), Murdoch (1980), Harvey (1974) and Sen (1981). These authors of diverse disciplinary background, contending with a broad array of questions, argue that increasing population numbers must be analyzed in a historical and more socially complex manner than simply invoking aggregate population parameters. Family size, they suggest, reflects rational economic decisions. The cost-benefit ratio of extra children is high for poor families in poor societies or societies where resources are extremely unequally distributed, because children contribute economically in agricultural labor or the informal economy to the household at an early age and continue to do so throughout their lives. Their opportunity cost, however, is relatively low.

The application of Malthusian perspectives in the Third World has remained central to the analysis of environmental degradation (Brown, 1982; Myers, 1980; Nicolaides *et al.*, 1982). In by far the most studied area of Third World environmental issues, the Sahel, a simple Malthusian

view has been sharply criticized (*cf.*, Watts, 1983; Franke and Chasen, 1980; and Hoskins, 1982) because of its lack of attention to the social and historical factors underlying the shift to larger animal and human populations. These authors argue that environmental problems have their origins in the structural poverty of rural populations. Rather than seeing population increase as an expression of natural law 'beyond the reach of human ingenuity' (Malthus, 1970), these authors argue that the decision to have children is a rational response to quite concrete economic factors. The point of analysis then should not focus at the correlation between population and poverty, but rather at historical and political economic issues that underlie reproductive choice.

The problem in much of the application of Malthusian framework is due to the strong correlation of population numbers with poverty and environmental degradation but their weak powers of explanation. Thus, as a 'theory,' Malthusian perspectives merely seek out generalized relations among various empirical objects and events themselves, and not abstractions about what produced them. As Ellen (1982) suggests, 'Crucial correlations are rarely those gross observable relationships between totalities, but the subtle, hidden connections between peculiarities.'

(b) *Economic perspectives on environmental degradation*

The economic analyses of Third World environmental issues usually fall into one of the three general categories. There is considerable conceptual relation between the three, and the ideas developed in one may be a sub-theme in another. The first can roughly be described as the 'Tragedy of the Commons'; the second, 'The Issue of Externalities' (often a function of the first); and finally, 'Dependency Perspectives.' The unifying idea of all of these centers on the concept that irrational land use leads to environmental degradation, and this irrationality can be understood through an analysis of issues associated with the economics of production.

Environmental degradation in developing countries is often perceived as a function of faulty property relations centered around the questions of common resources. In the original formulation by Hardin (1968), destruction of commons was triggered by population growth, and carried a strong Malthusian current within its analysis. The position can be roughly summarized by the idea that in the use of common resources, each economic actor seeks to maximize his individual utility. In the case of the commons, each individual garners the benefits of his additional exploitation, while the costs (in terms of environmental degradation) of each incremental increase in resource use are shared over all users, or society as a whole. Thus, there is a minor cost to the individual, but maximum potential gains. Each actor then will attempt to expand his exploitation competitively, with the result that the resource itself eventually collapses. The individual, personal rationality generates a collective tragedy. The two solutions proposed by Hardin to this situation are increased population control and the privatization of public goods to assure to their proper management.

Clarke (1974) has refined and expanded the ideas of the commons, pointing out that not only common property competitive exploitation, but also private maximization of net present value of profits, are central to the destruction of 'commons resources.' By focusing on discount rates, Clarke emphasizes that 'high discount rates have the effects of causing biological over-exploitation wherever it is commercially feasible.' It is thus often rational for entrepreneurs to accelerate their level of exploitation to the point of resource destruction and to reinvest their profits elsewhere. In Hardin's view, common resource externalities are not serious until population pressures make them so. Clarke, on the other hand, specifically points out that either competitive exploitation or certain mechanisms of capital accumulation produce the destruction of the 'commons.' Further, he emphasizes the mobility of capital, which makes it possible to avoid the longer-term economic consequences of resource degradation.

The 'commons' framework is most often applied in discussions of fisheries, grazing lands and, increasingly, forest resources. Counterarguments to Hardin focused on his Malthusian and 'Lifeboat Ethics' stance, but several critiques have also suggested that resources perceived as 'commons' reflect a variety of relations that were overlooked in Hardin's original formulation. The model rests on the neoclassical ideas that with private property, individual maximizers will rationally manage the resource to use the land or resource at its best and highest use and to remain competitive within the market. This assumes that markets are always the best means of allocating natural resources and that competition necessarily leads to appropriate management — propositions that are open to debate.

There are problems with these assumptions in the Third World context. First, formerly common resources are expropriated for commercial

use by private owners with privileged access. Those who were disenfranchized by the shift to private resources must then concentrate their use on the remaining common resource that soon becomes overused with distributional rather than demographic factors underlying overuse. Allocation in this context is not mediated by markets, but by class position. The remaining common resource in such situations also tends to be lower quality than the initial resource stock. Thus, it is not population *per se*, but tenure questions that lie at the heart of the issue. Second, commons often only appear to be so. Access to these resources is controlled by high entry costs where the resource is theoretically 'public' . . . but the ability to use them is severely limited. Contemporary whale and ocean fisheries are a fairly good example of such common property issues. Third, control of commons resources has historically been mitigated by a wide array of social mechanisms with complex distributional functions. Disruption of these mechanisms through wars, changing market structures structural changes can all result in the collapse of the controlling social structures that then can lead to degradation of the common resource. Fuel wood and grazing lands provide numerous examples of this phenomenon (Runge, 1981).

Implicit in the commons models is the idea that all the costs of production are not borne by the person who receives the benefits, but accrue to nature or society as a whole. This is the starting point of the analysis of externalities. Unlike the 'Tragedy of the Commons' approach, which essentially argues that the penetration of capitalist relations is necessary for proper natural resource management, the analysis of externalities reduces the scope of the commons issue from a historical-economic argument to a technical question, or one of mere market imperfection. The challenge is either technological or one of integrating the process into a market framework through the uses of taxes, subsidies and regulation. There is no question that some environmental questions can be resolved through only technical measures; but their implementation, almost without exception, requires the invocation of state economic manipulation through regulation. This thrusts such issues into the political realm.

Most writers on Third World environmental issues point out the high frequency of externalities (World Bank, 1975; Milton and Farver, 1968; Eckholm, 1982; Redclift, 1984; Murdoch, 1980). However, the political resolution of these questions is seen as profoundly problematic due to the structure and control of state power, the power of elites in Third World countries, the limited influence states have over both technology and investment choices made by national and foreign entrepreneurs, and finally the view that environmental deterioration is a necessary price for economic growth.

Commons/externalities frameworks focus on the *internal* organization of the resource management. By modifying internal production structure through privatization, technology and/or appropriate intervention, individuals will rationally manage their assets in a manner to produce a good for sale in competitive markets. The 'dependency' perspective, and the term is loosely used here, generally is concerned with the external factors acting on the production system that lead to environmental degradation. These factors include the orientation to and discipline by global markets; inappropriate international technologies, and the question of control over the revenues and responsibility for the consequences of the development process in intensive agriculture, or the exploitation of mineral or biotic resources (Sunkel, 1982; Mueller and Gligo, 1982).

The argument here follows roughly these lines. Historically, the major agricultural focus in international development concentrated on a few export crops; these tended to be the 'dessert crops' — cacao, coffee and sugar — or fiber crops like cotton, all of which compete for roughly the same market. Particularly in the case of short-cycle crops like sugar and cotton, the production process has become highly technical (in part because the United States is an important producer of these crops and US technology was often transferred 'wholesale'), and involves the use of a variety of fertilizer, pesticide and herbicide imports, in addition to heavy farm machinery. Environmental degradation occurs through a combination of the careless use of technologies evolved for different environments and different management regimes (Janzen, 1973; Milton and Farver, 1968) in the face of a substantially different and more complex biota. Further, the pressure for increased output often implies 'pushing' agro-ecosystems. Such an analysis is widely associated with export cropping, and can include a discussion of state promotion of particular commodities. The larger questions of control of revenues remain localized in the 'North–South' debate.

(c) *Technology assessment*

The issue of inappropriate technology, what Michael Todaro (1977) has called the 'false

paradigm' model, has increasingly come to the fore in analysis of environmental impacts. In this view, planners or agencies apply land use technologies that, due to local environmental or cultural conditions, are not well adapted to the area, and thus cause undesirable ecological effects. The literature on appropriate technologies is vast; but in practice, the focus of research is heavily weighted toward technological solutions and centers around genetic improvement and husbandry techniques.

This model does not try to replace environmental issues within an economic context except as a resolvable externality. Its most salient feature is its atheoretical approach that treats ecological issues as discrete problems associated with policy mistakes and a lack of fine tuning of the physical and biological technologies. It is not usually explicitly linked with any larger theories of environmental degradation, although Malthusian assumptions are often implicit in the 'false paradigm.'

I will argue that environmental degradation in much of Amazonia is not adequately explained by any of these models. Rather than analyzing regional ecological problems as strictly endogenous, due to population increase or to the use of inappropriate technologies, one needs to examine the role that Amazonian development (especially via cattle ranching) played in Brazil after the military coup in 1964. In both substantive and ideological ways, the development of Amazonia addressed the strong national as well as international pressures that confronted the new military government. These pressures led policymakers to choose cattle ranching, the *latifundia* land use *par excellence* over all other alternative land uses, as the defining strategy of Amazonian occupation (Hecht, 1982a).

The process of forest conversion and its consequences were implicit in the choice of cattle production. The factors that triggered continued conversion, in spite of the dramatic environmental costs and productivity declines, require a new environmental analytic framework that is linked to specific patterns of capital accumulation.

3. THE MILITARY COUP OF 1964 AMAZONIAN POLICY

(a) *The question of legitimacy*

In 1964, Brazil experienced a military coup of the type Barrington Moore (1968) would call a 'revolution from above.' Diverse political factions were supporters of the coup (Stepan, 1968), but its outcome was particularly favorable to certain groups: the agro-industrial and industrial entrepreneurial elite. The coup inaugurated a variety of changes, if not in kind certainly in emphasis, in the Brazilian economic scene. These transformations were reflected in increased international investment, the strengthening of entrepreneurial capital and significant modifications in the role of the Brazilian State in national and Amazonian planning.

When the military seized power, several basic political issues had to be addressed. First, the regime had to legitimate its right to govern. Second, it had to resolve many of the pressing economic constraints that had hampered capital accumulation by national elites (such as wage demands, high inflation, import industrialization policies and lack of investment outlets). Third, it was necessary to solve, or at least foster the appearance of contending with the social and political problems of rural areas, as reflected in stagnant agricultural production, low rates of investment and rural out-migration (Knight, 1971; Wood and Wilson, 1983).

Increased economic output was seen as a solution to the questions of legitimation and economic reorganization. The economic growth policies chosen by the new regime relied on increased international borrowing, a profound wage squeeze, augmented transnational participation in the economy, repression and conventional expansionist monetary and fiscal policies (Fishlow, 1973; Taylor *et al.*, 1980; Belassa, 1979). While the role of these policies in spurring the 'Brazilian Miracle' is open to question (Taylor *et al.*, 1980; Fishlow, 1973; Belassa, 1979; Singer, 1982; Malan and Bonelli, 1977), the regime took credit for the rapid growth of the Brazilian economy during the 1968–73 period. This unusual economic performance, triggered by massive borrowing, foreign investment and an exceptionally active world market, aided in the institutionalization of the various military regimes that followed the 1964 coup.

Agricultural and agrarian questions required a profound shift in policy as well. Except for a few exports, the Brazilian agricultural sector in the late 1950s and early 1960s suffered from a lack of credit and investment capital, import tariffs that made the cost of inputs such as machinery and agricultural chemical stocks very expensive, export taxes and marked regional disparities in investment. Overvalued exchange rates made Brazilian agricultural products relatively costly on the international market, while national policies emphasized exports only as a vent for surplus production (Knight, 1971). Structural change and mechanization in Brazilian agriculture began to erode access to land for tenant

farmers and sharecroppers, while the closing of the southern frontiers of Parana and Rio Grande do Sul further reduced agricultural options for the rural poor (Foweraker, 1980).

Attempts to confront the situation in the countryside took the form of increased availability of funds for agriculture. Policy mechanisms for agricutural change included subsidized interest rates for rural modernization, mechanization, export incentives, and revaluation of the *cruzeiro*. The greater availability of financing for investments in the agricultural sector was intended to modify the production processes on the farm and in specific regions. The agro-industrialist elites, as well as urban entrepreneurs, were attracted to agriculture by the subsidies, for diversification of their investment portfolio, and to take advantage of tax credits. These initiatives would ostensibly promote greater efficiency and rational economic behavior, compared with that of semi-feudal elites and through essentially a diffusion effect, would transform agricultural production in Brazil.

The agrarian question, whose outwards symptoms were accelerated rural to urban migration and increasing peasant activism, was addressed by the new regime by repression in areas of insurrection, such as the Northeast and Parana, and the opening of a new agricultural frontier, Amazonia. Amazonian development obviated the need for land reform, and implied a national will to include the rural poor in the government's development strategy.

The occupation of Amazonia was an idea that resonated closely with other ancillary themes in the government programs. Among the most important was the military ideology of National Security. The large size of Amazonia (more than 50% of the Brazilian territory), with its sparse population and unpatrolled border shared with eight other countries, and with a history of annexation and border conflict between them, fueled a certain disquiet about the area. The geopolitical importance of Amazonia, reflected in the slogan '*Integrar para nao entregar*,' is present throughout the Amazon planning documents.

The military language characteristic of the development rhetoric also contributed to the sense of Amazonian occupation as the moral equivalent of war. Ideologically, such a military focus unifies national factions around a common national goal and justifies current sacrifices in welfare for a larger (future) good. Thus, General Castello-Branco stated in 1964 that 'Amazonian occupation would proceed as though it were a strategically conducted war,' and the first post-coup body of legislation concerning the Amazon had the appropriately military title of 'Operation Amazonia.' Not only would Amazonian occupation function like a war in the ideological sense, but it would also stimulate the economy in a like manner through construction and heavy industries linked to infrastructure development.

The concept of national security was closely allied to that of national integration, another common policy theme. The latter, in turn, can be seen as a version of Manifest Destiny, an idea consistent with the orthodox economic approach to the region. '*Integracao Nacional*' implied greater economic linkages of the Amazon hinterlands to urban centers, facilitated by the development of infrastructure and the creation of investment credits. The attack on regional disparities held out the image of the developed center-south — Sao Paulo and Rio — as the achievable future of Brazil's backlands. Further, through regional occupation, the riches of Amazonia, rightfully Brazilian, could be realized and contribute to the overall welfare of Brazil.

Through national security and manifest destiny, backed by infrastructure and investment, the new agricultural frontier in the Amazon was to provide a solution to vital economic and ideological questions, and thus served important political and legitimizing functions to the new regime. The role that cattle ranching was to play in this process can only be understood through an appreciation of the internal and international pressures that influenced the new government.

(b) *Internal pressures underlying policy*

Significant internal pressures came to bear on the new military regime (Stepan, 1968; 1973). Urban unrest required police coercion, and the wage squeeze on workers characteristic of the post-1964 regime (Bacha, 1977; Fishlow, 1973; Malan and Bonelli, 1977) exacerbated dissatisfaction (Stepan, 1973; O'Donnell, 1979). Since few other concessions were granted to labor by the regime, cheap food policies (especially for beef) were important priorities (Leff, 1967; Bergsman, 1970). The beef industry in the early 1960s, however, was at a cyclic production low, with price ceilings making cattle production uneconomic for producers, while urban and international demand soared.

The capacity of traditional landed elites to respond to this crisis was perceived as dubious, while the technological orientation of agribusiness and the entrepreneurial spirit of parts of the industrial sector, coupled with the new Australian pasture technologies, seemed a reasonable

solution. The apparent viability of this avenue was contingent on the extent to which long-term credit could be made available and antiquated production bottlenecks could be circumvented. These credit and production constraints could be addressed without drastic structural change through increased agricultural lending and horizontal expansion of land use through the sale of state properties to agro-entrepreneurs.

The expansion of cattle production had other attractions since it was consistent with the desire to expand exports of 'non-traditional' Brazilian products, a fundamental feature of the new regime's economic policy. Little was known about Amazonian ecologies, but the 300-year history of ranching on the island of Maranjo and the existence of upland natural grasslands made it appear that only technical insufficiency limited the productivity of livestock in the region. Further, compared with the other agricultural options in the region, such as pepper, cacao and rubber plantations, ranching seemed relatively easy to implant and maintain and had low labor requirements. A semi-skilled labor pool (cowboys) for ranching existed and were easily available from Goias, Mato Grosso and the Northeast. Moreover, periodic droughts in the Northeast and generally miserable conditions there assured a supply of unskilled workers who could be recruited by labor contractors (*empreiticiros*) to clear land for pasture. The flexibility of animal marketing and the fact that animals could be walked to market if bridges collapsed or roads became impassable were also attractive. Finally, the use of corporate entities was viewed favorably because these would have the administrative capability to resolve certain infrastructural problems (e.g., public health, communications, food supply) that otherwise would be the costly purview of the government. Except for financing and major infrastructural development, the actual involvement and responsibility of the government would be minimal. The larger economic and political concerns of the government, as well as the practical considerations of the actual physical occupation of the region, made ranching seem an attractive solution to these problems.

The expansion of ranching into the Amazon was also conditioned by high inflation periods of the 1960s and 1970s that increased land speculation. As the latter parts of this article show, the fiscal incentives and land concessions provided by the government in Amazonia facilitated land acquisition and contributed to the extreme increase in the value of land in the region. Those who invested through SUDAM (Superintendency of Amazonian Development) and other cattle projects could make enormous capital gains simply through the increased valorization of land.

(c) *International factors affecting policy*

International factors implicitly or explicitly played an important role in the evolution of ranching as the main development strategy for the Amazon, primarily through the expanded global demand for beef during the mid-1960s. This increased demand reflected both changes in the US production system and rising European and Middle Eastern purchases. Feder (1979) has pointed out that changes in the US beef production system were important in the expanded global beef demand and in the increased lending for the livestock sector by international agencies.

In the 1950s, the United States embarked on a program to increase the production of high-quality beef using the feedlot system. Grain-fattening of cattle was also a means of disposing of surplus wheat and corn, a serious problem in the late 1950s and early 1960s. Feedlots were capable of generating large tonnages of high-quality beef, but the success of this production system was not without some difficulties. In particular, demand began to soar for lower-quality, utility beef used in fast foods and sausages. Utility, or cutter beef, is expensive to produce by the feedlot system, and suppliers turned to international sources for beef. The rise in US demand occurred at the same time that meat consumption and demand increased in Europe, the Eastern Bloc and Japan. Since South American (as opposed to Central American) beef has traditionally been oriented to European markets, the expanded purchasing power of these countries in the mid-1960s was a major stimulus to demand.

The general international perspective for the expansion of Brazilian beef is summarized by FAO/ECLA's (1964) study called *Livestock in Latin America*. The FAO document indicated that although Brazil's existing productive capacity was rather low, it had great potential for expansion through the incorporation of new land and the rationalization of production. The FAO argued that overcoming certain bottlenecks, primarily related to credit, was essential if Brazil were to capture a sizeable market share. This document concluded that global beef markets were buoyant and would continue to expand as national and international demand increased, a tendency that was particularly strong in the early 1960s.

Finally, Brazil was seen as an appropriate area for the transference of the Australian pasture

technologies. If the conditions of long-term credit and better grass varieties were met, FAO pointed out that Brazil could become one of the premier beef exporters. This influential document frequently underlay the great push toward ranching throughout Latin America in the early 1960s (see, for example, Parsons, 1976), the precise period when policy for the Amazon was being developed. The various international agencies, such as the World Bank, were able to argue that with the proper technology and better credit lines, livestock represented an excellent investment for development. As a consequence, during the mid- to late-1960s, financial resources poured into livestock projects.

For many years, World Bank loans had supported livestock development on a relatively small scale. From 1948 to 1960, 4% and from 1960 7% of all loans went into the livestock sector. Between 1966 and 1970, this percentage jumped to 21%. In the years 1959–73, a total of 63 loan projects were approved involving $839.2 million plus $1,004 million in counterpart funds. For the period of 1974–80, the Bank planned on 70 loan projects involving some $1.4 billion of which 63% was to go to Latin America. Thus, the Bank was to lend in seven years more than it had spent during the previous 15 years on beef production.

The Inter-American Development Bank statistics reveal the same general trends as those of the World Bank. The amount of livestock loans authorized during 1971–76 increased in the aggregate by 120% while for agriculture as a whole, they increased by only 38% (IADB Annual Reports).

The total direct livestock support given by the World Bank and the IADB in the late 1960s and the 1970s, not including general infrastructure loans, was about $1.3 billion. Indirect and counterpart funds provided an additional $5–$7 billion. To estimate private foreign and domestic investments in the beef cattle systems is virtually impossible, but at least a billion dollars have been invested in the SUDAM Amazon projects alone. Feder (1979) suggests that public and private investment in cattle ranching development is minimally $15 billion. By 1983, roughly 75 projects containing livestock components had been financed by the bank. The total cost of these 75 projects alone was $7 billion, of which $3 billion was for livestock (Jarvis, 1984).

The international investment picture coincided very well with Brazil's own development ambitions and dovetailed with Brazil's geopolitical and balance-of-payments concerns. It was against the backdrop of these internal and international pressures that, after several trips to the Amazon, General Castello Branco, the first military president after the coup, laid the groundwork for the far reaching legislation that was to become known as 'Operation Amazonia.'

(d) *Operation Amazonia*

In late 1965, General Castello Branco began what he described as a new era in Amazonian planning that would set the tone of the region's development. He emphasized that planning would occur in an ambience where technical considerations would take precedence over clientelistic interests that had dominated the previous planning agency, SPVEA (Superintendency for the Economic Valorization of Amazonia). He stressed greater efficiency in planning and emphasized the enhanced role of private enterprise in regional development. The government would provide infrastructure and general funding for development, while the actual task of regional occupation would be carried out by the entrepreneurs.

The fundamental legislation for Operation Amazon was Law 5.1744 (October, 1966), in which fiscal incentives were provided for the Amazon. These incentives stipulated that 50% of a corporation's tax liability could be invested in Amazonian development projects, essentially permitting taxes to become venture capital. The projects could be new ones or the expansion of existing enterprises. Since several southern Brazilian land magnates already had substantial land investments in the Amazon, this was an attractive means for valorizing existing holdings.

The government provided exemptions of 50% of the taxes owed for 12 years, to enterprises already established in 1966, and exemptions of up to 100% for projects implanted prior to 1972. Qualifying firms were permitted to import machinery and equipment duty-free, as well as being exempted from export duties for regional products (for example, timber). The various states of the region also provided their own incentives and inducements (land concessions, usually), while international credit lines such as those from the Inter-American Development Bank provided special agricultural development credit that could be mobilized for Amazonia (Pompermeyer, 1979). These incentives differed from previous development funds in the magnitude of resources, but more importantly in that land acquisition could be stipulated as part of the development costs.

Another incentive to the private sector was FIDAM (Funda para Desenvolvimento da Amazonia), which was to receive 1% of federal tax

revenues, proceeds of BASA (Banco da Amazonia) securities and fiscal incentive funds not applied to specific projects (Mahar, 1979). These would be invested by BASA in research and various private firms. The result of these various incentives was that the federal government would supply 75% of the investment capital needed for the enterprises.

The new incentive laws also raised the ceiling from 50 to 75% of capital costs and had more generous grace periods. Another important aspect of the incentive legislation was the eligibility for fiscal incentives of foreign corporations, a rider that had not existed previously. Although foreign investment in Amazonia is often discussed (Kohlhepp, 1978; Davis, 1977; Ianni, 1978), the magnitude of foreign investment in the agricultural sector in Amazonia is comparatively low compared to Brazilian national investment. Evans (1979) has aptly pointed out that, in general, the foreign investor is a poor candidate for the entrepreneurial role when information is low. Further, foreign investment in Brazil was characterized during the 1964–78 period by its involvement in the industrial sector rather than agriculture, and in the post-1975 period by its emphasis on mining when engaged in rural activities.

The combination of fiscal incentives and other credit lines resulted in an explosion of ranching in Amazonia. The number of SUDAM projects approved after 1964 and the level of SUDAM investments is presented in Figure 1. The peak investment period was 1967–72 as investors began to implant projects prior to the 1972 cutoff date for the 12-year tax holiday. During these five years, SUDAM approved some 368 new projects. By 1978, 503 cattle projects had been approved and of these, 335 were new projects, while 168 were reformulations, or expansions of existing SUDAM projects. By 1978, about $1 billion of SUDAM funds had been invested in these ranches, or on the order of $2.6 million per ranch in direct investment. The other loans applied to these ranches represented another subsidy that is almost impossible to assess.

Throughout the 1960s, livestock production was publicized as the most promising investment to be made in the region. As the president of BASA (Banco da Amazonia), Lamartine-Nogueira (1969), put it:

> Ranching . . . is an activity that has all the necessary conditions to be transformed into a dynamic sector of the northern economy . . . the fiscal incentives and road construction have generated a remarkable preference for livestock, and for this reason, a new era in the sector is opened.

Not only was there a marked preference for ranching, but also bias to certain regions: northern Mato Grosso, southern Para and northern Goias. The extraordinary fiscal incentives and the (seemingly) relatively low risk associated with ranching created an unparalleled opportunity for gaining control of land. As Mahar (1979) has shown, investment in crop production in the Northeast (where incentives were also available) was comparatively risky, as is most cropping in the North. But, if land values increase, then the desire for investment becomes intelligible because land tends to hold value in inflationary economics. This was certainly the case in Brazil throughout the 1960s and 1970s. Infrastructural development in an area like the Amazon also increases the value of land. The influx of incentives that permitted the acquisition of land as part of the development costs created a situation where, as Mahar has noted, the value of Amazo-

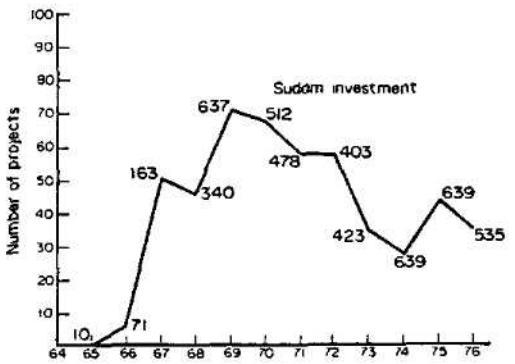

Figure 1.

nian land was increased at 100% per year in real terms. This is shown in Figure 2. This speculative process was driven in part by the hope of future production returns, or the value of future resources; but land, and its modifications by ranching, became the primary vehicle for capturing enormous state subsidies.

As we show later in this paper, the nature of land in the Amazonian economy began to change in a fundamental way. Land itself, and not its product, became a commodity since even lands whose productivities were declining increased in value in this speculative context. What became crucial at this juncture was the emphasis on the exchange rather than the use value of lands.

By the late 1960s, considerable controversy began to mount over the expansion of corporate livestock operations, both for ecological and social reasons. In part as a consequence of the very obvious bias toward large holders and the pronounced drought in the Brazilian Northeast, in 1970, President Medici embarked on a new policy direction for the Amazon.

(e) *National integration program* 1970–74

Other possible causes of the change in policy emphasis from large- to small-scale holders are discussed at length in other sources (e.g., Pompermeyer, 1979; Mahar, 1979; Wood and Schmink, 1979; Bunker, 1979; Smith, 1976). The new National Integration Program (PIN) shifted the focus of Amazonian occupation from the purely 'economic' to a 'social' perspective. Instead of 'Amazonia as your best business,' it was to be '*O Homen e a meta*' (Man is the goal). Faced with the misery of the drought-wracked Northeast, the 'men without lands' would be linked via the Transamazon and other infrastructural programs to the 'lands without men' in Amazonia. A more cynical version of the new programs saw the Transamazon linking 'poverty and misery.' The new policies expressed in PND I (the first National Development Plan) reiterated the themes of the agricultural frontiers as escape valves for surplus population, the importance of national security and the necessity of national integration.

The goals of the entrepreneurs and of advocates of small-scale Amazonian occupation came into sharp conflict. Inter-ministerial rivalry between SUDAM (which had not retreated from its position that corporate development was the best means of Amazonian occupation) and INCRA and the Ministry of the Interior became quite severe, as Pompermeyer (1979) and Souza-Martins (1983) have documented. During the 1970–74 period, INCRA, due to its contradictory roles, pressures from a variety of interest groups, inter-agency rivalry and its advocacy of social occupation, came under sharp attack (Bunker, 1979; Pompermeyer, 1979). By 1974, as the ecological and production problems of the Transamazon became acute (Smith, 1976; Moran, 1981), the Association of Amazonian Entrepreneurs was able to reassert in policy its position that large-scale occupation was the only rational means of occupying the region (Pompermeyer, 1979). The crises within INCRA and in Amazonian policy were constantly linked to the ideas and ideologies of 'social' vs 'economic' occupation. Brazil's worsening economic situation, it was argued, made social concerns a luxury. The tensions became so extreme that it became necessary to sell ten areas of public land (under

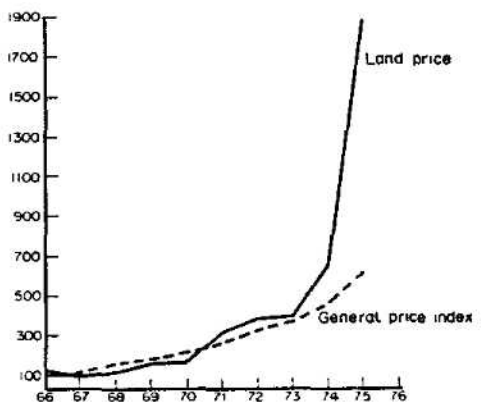

Figure 2.

INCRA control) of 50,000 hectares so that SUDAM could designate a new group of entrepreneurs for ranching development. Reis Velloso, the Minister of the Interior, then travelled along the Transamazon with 20 entrepreneurs to whom he offered land that had been reserved for colonization and agrarian reform (Pompermeyer, 1979).

(f) *The program for Amazonian Development* 1975–79

In August of 1973, after his junket to the Transamazon, Velloso addressed a meeting in SUDAM and articulated the policy shift that would be formalized in PDAM I (The Amazon Development Plan):

> Until now, the Transamazon has emphasized colonization, but the necessity of avoiding predatory occupation with consequent deforestation, and of promoting ecological equilibrium, leads us to invite large enterprises to assume the tasks of developing the region.

In the same document, Velloso offered another 2.5 million hectares of colonization lands for private investment.

SUDAM and MINTER followed these pronouncements with a series of documents criticizing the functioning of INCRA and the idea of attempting to solve the problems of the Northeast by transferring them to the Amazon. Further, the colonization programs had generated a great deal of spontaneous migration (Aragon, 1978). These migrants were viewed as agriculturally ignorant: '(They) carry out the only and dangerous activity they can undertake: deforestation and the exhaustion of soil for subsistence agriculture' (SUDAM, 1974). The same charge could just as easily be made against ranching enterprises. With the publication of PDAM I, the economic emphasis on large-scale entrepreneurial development was once more reasserted.

This document, and the PND II (the second National Development Program), prefaced the Amazonian sections by pointing out that cattle had acquired special importance in the region during the preceding decade as a function of the expansion of global markets for beef, although at the time of this pronouncement, global beef markets were quite depressed. The reports also indicated that 60 million hectares of Amazonia were suitable for ranching at stocking rates of about one animal unit/hectare. It was further argued that Amazon meat production 'must be fundamentally oriented to external markets whose demand will surpass rapidly the global supply' (MINTER, 1975).

With the caveat that ranching would be best development in the *mata fina* of southern Para and Mato Grosso and in some *cerrado* regions, areas where large-scale ranches already predominated, ranching was reinstated as the main development trajectory. The re-emphasis on cattle was associated with the perception that cattle actually improved soil nutrients and represented an environmentally sound alternative to other agricultural enterprises. The question of the environmental effects of converting forest to pasture, particularly in reference to soil resources, is discussed in the next section.

4. CONVERSION OF FOREST TO PASTURE: DEVELOPMENT OR DESTRUCTION

Among those who have investigated the soil effects of forest conversion to grassland in the Latin American tropics, and the subsequent performance of these pastures, there have been substantial differences in opinion. Goodland (1980) and Fearnside (1983) have argued that ranching represents the worst of all conceivable land-use alternatives for Amazonian development due to the high ecosystem losses relative to the short-term profits and low employment potential. Myers (1980), Fearnside (1978), Hecht (1982a) and others have argued, for a variety of reasons, that ranching is a relatively unstable and unproductive land use for the region. Others, notably Serrao *et al.* (1979), Alvim (1980) and Falesi (1976) disagree. Central to the forest to pasture controversy is a widely cited study by EMBRAPA (Empresa Brasiliera de Pesquisa Agropecuaria) the research arm of the Ministry of Agriculture.

The EMBRAPA study (Falesi, 1976) maintained that conversion of forest to pasture improved soil properties, particularly for Ca, Mg and pH. Increases in P were transitory, although economically questionable. These results were frequently used by the Ministry of the Interior in policy conflicts to help undermine small-scale agricultural credits. Peasant agriculturalists were perceived as ecologically damaging, while large ranchers were portrayed as environmentally rational.

Based on the EMBRAPA results, it was suggested that 'the formation of pastures on low fertility soils is a rational and economic means by which to rationalize and increase the value of extensive areas' (Falesi, 1976). Serrao *et al.* (1979) argued that 'the subsequent substitution of pasture with perennial crops would require only a small amount of P fertilizer for develop-

ment . . . due to the favorable conditions of the majority of the soil's components after a long period under pasture.' In the international development literature, Cochrane and Sanchez (1982) indicated that 'The data suggest a remarkable degree of nutrient cycling and maintenance of soil fertility under pasture . . .. These data are encouraging because they indicate a very high beef production potential with minimum inputs.'

In spite of such optimism, the roughly 10 million hectares of land converted from forest to pasture in Brazilian Amazonia do not appear to be particularly stable. Estimates of the area of severely degraded pasture range from 15% (Toledo and Serrao, 1982) to 50% (Tardin *et al.*, 1977; Santos *et al.*, 1979; Hecht, 1982). The major factors involved in pasture land degradation include soil nutrient changes, compaction and weed invasion.

In the next section, I summarize data on soil changes on a clay-loam oxisol in the major cattle areas in eastern Amazonia, comparing more recent research with the EMBRAPA study. Methodological issues and the differences between the studies are presented in more detail elsewhere (Hecht, 1982a). The most important difference, however, is that of sample size. The EMBRAPA study was based on five samples per age class, while this study involves eighty samples per age class of pasture.

(a) *Results of conversion studies*

(i) *Effect on soil pH*

When forests are felled and burned, an increase in pH occurs as the bases held in the biomass are transferred to soils, regardless of the land use implanted (Nye and Greenland, 1960; Sanchez, 1976). As Figure 3 shows, there are substantial increases in the soil pH of the sites examined in the EMBRAPA study. By contrast the clay-loam oxisol showed only a moderate pH unit rise. Though the ranges of pH in the clay loam included some values as high as those of the other sites, as the number of samples increase, the pH increases are less dramatic. This result is corroborated in another data set (presented in Sanchez, 1976) that analyzed soil changes before and after deforestation on 60 sites. These samples were analyzed at the EMBRAPA laboratories. One of the interesting aspects of the pH data is that the liming effect is maintained through time. Cochrane and Sanchez (1982) and Toledo and Serrao (1982) believe that efficient nutrient cycling on the part of the grasses is responsible for the persistence of the pH improvement. While Tietzel and Bruce (1972) have shown in Australia that *Panicum maximum* (the most widely planted grass species in the Amazon) is a reasonably effective cycler of Ca, Mg and K, there is an alternative interpretation

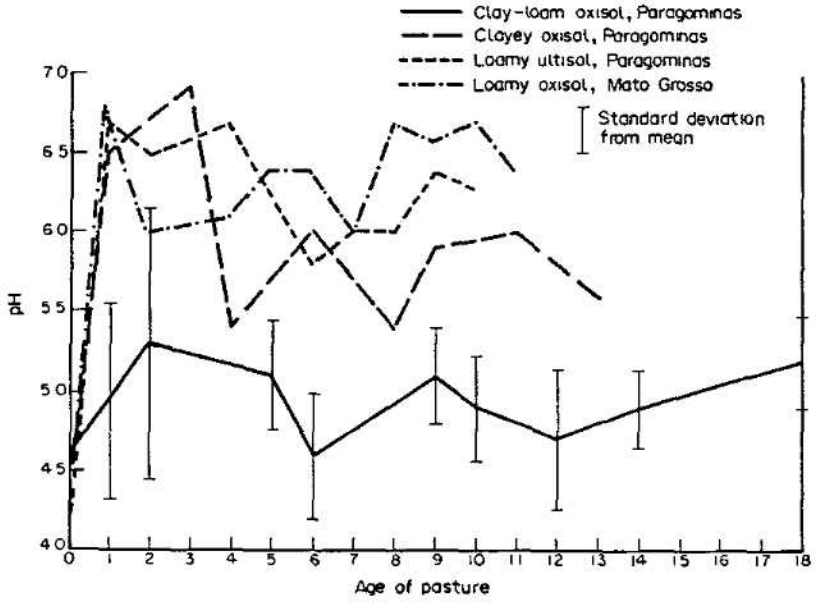

Figure 3. *Changes in pH after conversion of forest to pasture. Sources: Clay-loam oxisol from Hecht (1982a); clayey oxisol, loamy ultisol and loamy oxisol; from Falesi (1976).*

that also merits consideration. When forests are cut and burned for pasture formation, only about 20% of the slash actually combusts (Olsen, 1968). Since 80% of the total ecosystem Ca, Mg and K are stored in tree boles, their gradual decay after cutting could supply these elements at a rate that could maintain the pH. Since the maintenance of pH is recorded for other agricultural systems after forest conversion (Bandy and Sanchez, 1981), it may be that cycling is less important than slash decay. This hypothesis, of course, does not exclude the possibility of nutrient cycling by the grasses. But, in fact, it appears to. pH levels are probably maintained by inputs via slash decomposition. Once decomposition has run its course, the implication is that pH will fall.

(ii) *Soil calcium and magnesium*

Closely associated with the increase in pH are additions of Ca and Mg to soil. The rise in these elements (and their variability) is most pronounced in the years immediately following clearing. Since rainforests store over one ton each of Ca and Mg per hectare (Klinge *et al.*, 1975), and the ash additions after burning supply immediately at least 100 kg of Ca (Seubert, Sanchez and Valverde, 1977), the rise in Ca and Mg after conversion is not surprising (see Figure 4). While soils may be improved in terms of Ca and Mg contents, in fact, the overall level of these elements is below that critical for pasture production (Coordenadoria de Assistencia Tecnica Integral, 1974).

(iii) *Soil potassium*

Potassium is a monovalent cation (an ion with one positive charge) that is stored mainly in the vegetation in tropical ecosystems, cycles quickly and is quite vulnerable to leaching. In general, more than one ton of K per hectare is stored in the forest biomass. Due to the mobility of this element, K values are quite erratic throughout the pasture sequence (see Figure 5) reflecting periodic burning, weed invasion and other management activities. The coefficient of variation of this element is so high, however, that there is no statistical significance between the K values of forest and pasture (Hecht, 1982b). Soil improvement of K after conversion is thus open to question as is decline in K. Deficiencies of this element have been documented for pastures in Paragominas, Brazil (Koster, Khan and Bosshart, 1977). The high value for K in the Mato Grosso oxisol probably reflects an initially high K level, as well as a greater frequency of palms, both in the native vegetation and in the pasture weed invaders. Palms have a relatively high level of K in their leaves (Silva, 1978).

(iv) *Phosphorus levels in soil*

The most crucial element for pasture production in Amazonia is P (Toledo and Serrao, 1982), and 10 ppm is usually considered the minimum value for sustained production of pastures. After conversion, P values increase dramatically, as Figure 6 indicates, but after the fifth year, they tend to continuously decline to a level of about 1 ppm.

The decline of P has been identified by some researchers as the main reason for pasture instability in Amazonia (Serrao *et al.*, 1979). The high demand of Panicum for this element, coupled with losses due to erosion and animal export, as well as the competition the grass undergoes from weeds adapted to low P levels,

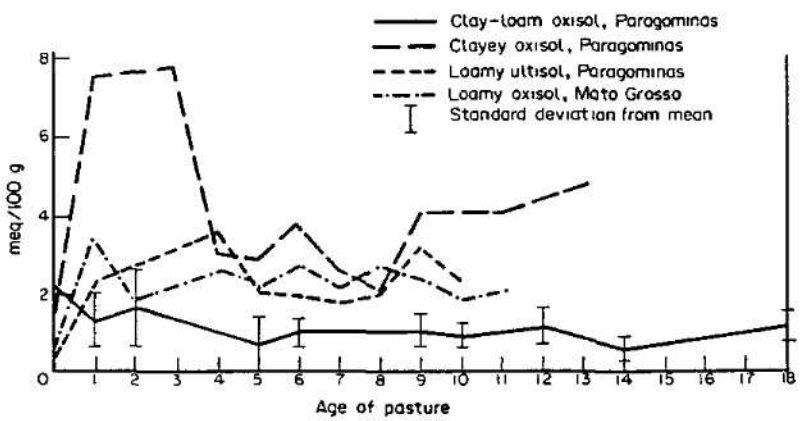

Figure 4. *Changes in Ca and Mg after conversion of forest to pasture. Sources: As for Figure 3.*

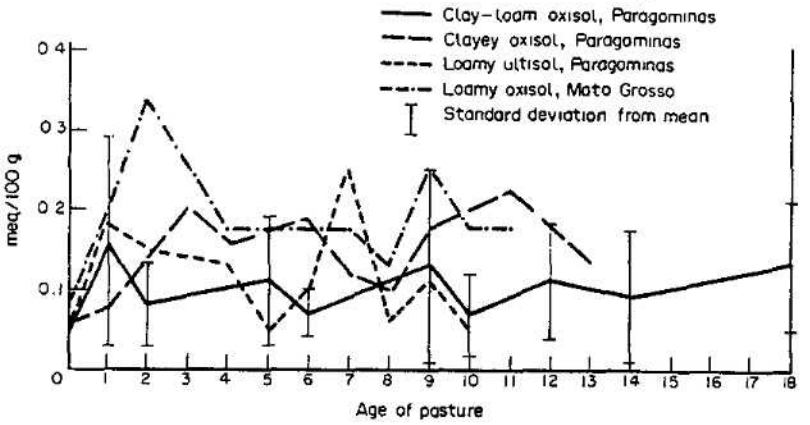

Figure 5. *Changes in K after conversion of forest to pasture. Source: As for Figure 3.*

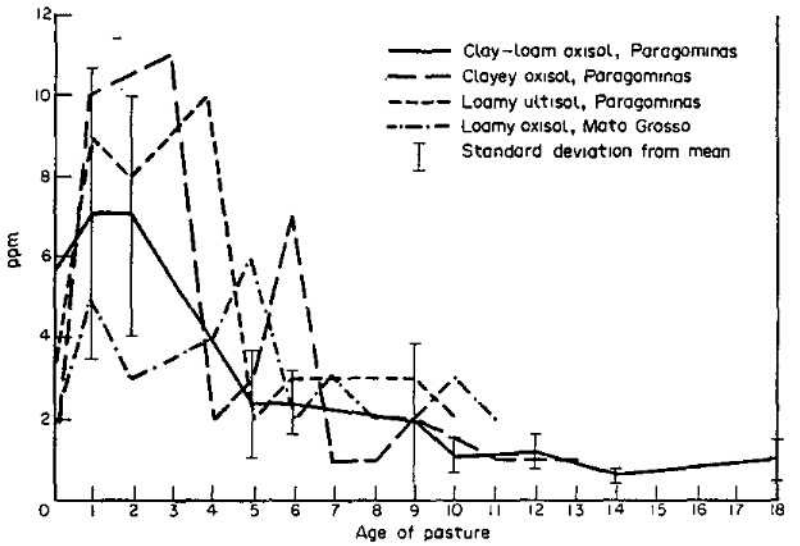

Figure 6. *Changes in P after conversion. Source: As for Figure 3.*

lead to drastic drops in productivity, which often result in pasture abandonment. Although the grass responds well to fertilization (Serrao *et al.*, 1979), the high transport, application and opportunity costs, as well as erratic availability of P, make widespread fertilization uneconomic at this time.

(v) *Soil nitrogen*

Soil nitrogen values reflect nitrogen-accumulating activities like N fixation, additions from the atmosphere and organic matter decay, as well as N-decreasing activities like volatization, denitrification, leaching, erosion and plant uptake. Many of these processes are mediated by the biota, and rates of loss and addition are affected by environmental factors (pH, temperature, soil moisture). Nitrogen is an element that can vary strongly from site to site. As Figure 7 suggests, the Paragominas ultisol shows a slight initial increase and a subsequent equilibration, indicating that differences between forest and pasture N soil storage are insignificant. In the clay-loam oxisol, soil N decreases, but when

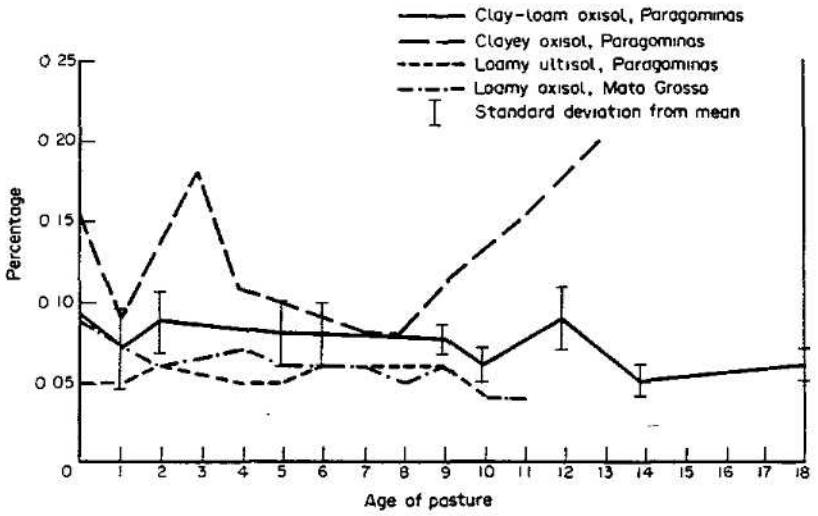

Figure 7. *Changes in N after conversion of forest to pasture*
Source: As for Figure 3.

analyzed through multiple range tests, pasture soils are not significantly different from forest soils, except in the oldest pastures and during the first year after clearing (Hecht, 1982a).

The heavy clay oxisols from Paragominas and Mato Grosso both show N declines although the Paragominas samples are decidedly more erratic. The high N values in year 13 in the Paragominas heavy clay soil may reflect N fixing by native weedy legumes. On the other hand, the Mato Grosso site N levels decline by 50% after conversion.

(vi) *Organic carbon in soil*

Soil carbon levels often drop with burning, but they can increase if there is an addition of fine charcoal, which probably occurred in clay-loam and loamy oxisols, and the loamy ultisol (Figure 8). Levels of C can increase due to slash decomposition, organic matter additions from the grass and heavy weed invasion, but such gains can be short-lived. In the Mato Grosso oxisol and Paragominas ultisol, C declined after clearing. In the Mato Grosso site, the value dropped to 50% of the forest level.

(vii) *Summary of soil findings*

The effect of conversion of forest to pasture on soil chemical properties can be described as relatively neutral for N and K, negative for P and C, and mildly positive for Ca, Mg and pH, particularly in the first years after clearing. The widely cited 'dramatic increases' in these elements after conversion seem to be moderated when larger sample sizes are used. In any case, the absolute levels of Ca and Mg are low-to-marginal for pasture production. Soil nutrients during the first five years are adequate for animal stocking rates of one animal unit (au) per hectare, but drop to 0.25 au/hectare after five or six years. This is due not only to soil chemical changes, but also soil compaction and weed invasion.

(b) *Other factors affecting pasture productivity*

Soil physical changes also affect productivity. For example, soil bulk densities that double with increasing pasture age reduce infiltration that influences sheet and other types of erosion. Amazonian pastures are rapidly invaded by shrubby weeds that reduce pasture productivity by competing with forage grasses for nutrients and water. Although many weed species are in fact browsed by animals, weed control is expensive and absorbs about 20% of a ranch's operating cost. Ranches that did not receive fiscal incentives are squeezed between declining productivity and escalating weed and infrastructure repair costs. Not surprisingly, when livestock operations pass the five-year mark, they are often repossessed or sold. By 1978, about 85% of the ranches in Paragominas had failed, according to the Director of the Para State Cattlemen's Cooperative.

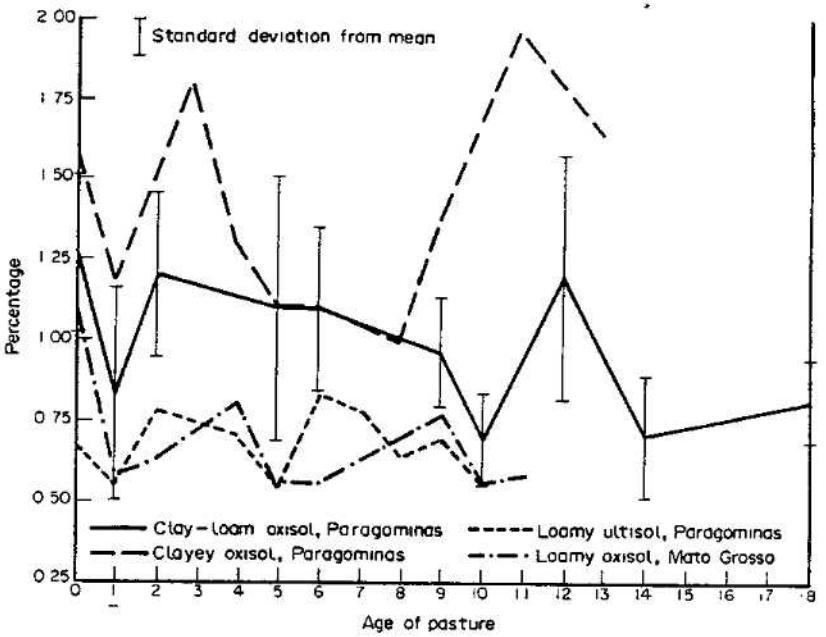

Figure 8. *Changes in carbon after conversion of forest to pasture. Source: As for Figure 3.*

(c) *Accumulation and environmental decay*

Even as pasture productivity declined, for the reasons mentioned, the value of pasture land increased due to the infrastructure development, mineral resource potential and the generous fiscal incentives and sweetheart loans made available to investors. The creation of a land market in Amazonia where previously none had existed generated an extraordinary speculative boom that held sway throughout the 1960s and 1970s. What is essential here is that the exchange value of the land itself was far higher in this speculative context, than any commodities it could produce. Entrepreneurs depended for profits, *not on the annual productivity of the land, but on the rate of return to investment.*

Whether ranching achieved many of its hoped for results is quite dubious and requires a more extensive analysis than can be presented here (see Mahar, 1979; Pompermeyer, 1979; Hecht, 1982). However, pastureland created from forests is expensive to implant and to maintain, and the value of the animal product does not recompense its production costs even with large subsidies (Hecht, 1982a; Possio, 1984).

Declining pasture productivity was not the only consequence of converting forest to pasture. Ranching expansion played a key role in marginalizing small landholders as land increasingly came under the control of large estates. Areas where ranching dominated, such as the south of Para and the north of Mato Grosso, were characterized by land distributions, where 6.7% of the landholders controlled fully 85% of the private sector lands, while almost 70% of the remaining farms owned merely 6% of the area. Along the Belem-Brasilia Highway, one of the earliest upland cattle ranching areas, Gini coefficients for land owning increased from 0.66 to 0.77 in the years between 1967 and 1975 (Santos, 1979), indicating extreme land concentration. Such marginalization produced a great deal of land conflict (Souza-Martins, 1983; Schmink, 1982).

5. ENVIRONMENTAL MODELS AND THE AMAZONIAN CASE

I would like to return now to the earlier sections of this article where the main models used to explain land degradation in the humid tropics are discussed: Malthusian, economic dependency and technology assessment approaches. I will describe why each of these models does not adequately explain the dynamics of environmental deterioration in the eastern

Amazon and why a more complex framework for analysis of international environmental problems must be developed.

The Malthusian perspective, as it has been applied to Amazonia, generally asserts that while shifting cultivation may be ecologically sound at low human population densities, it becomes environmentally destructive when demographic increases reduce the land/person ratios, and fallow times are shortened so that land cannot recover its production potential after an agricultural cycle. Soil fertility declines from overuse, weeds hamper crop production, and erosion results.

There is no question that much of the shifting cultivation observable in eastern Amazonia along roads and in colonization areas follows such a pattern of land deterioration, but this phenomenon is unrelated to human population numbers or physical availability of land. Roughly 12 million people live in the Brazilian Amazon, a region that encompasses about 60% of the Brazilian national territory. Amazonia itself encompasses close to 5,000 km^2. It it ludicrous to describe the environmental degradation in this situation as only a function of demographics. Rather, the situation is due to the extraordinary maldistribution of land, as the figures cited in earlier paragraphs show. Further, these slash-and-burn cultivators are often harassed by large landowners or land speculators and are unable or unwilling to cultivate carefully because they have no title and even their short-term squatters rights may be violently curtailed.

Commons models and externalities frameworks do not apply well to the Amazonian situation because, in fact, there has been a rapid shift to private property which has been associated with the increase, rather than the decline of environmental degradation. The externalities: extinction, climatic and hydrologic, that occur in Amazonia remain in the realm of debate. No species has been certified as extinct, although undoubtedly many have gone out of existence. Since a large percentage of species has never been catalogued, at this time we know neither the organisms nor the value of the organisms that have passed from this earth. The existence of climatic and hydrological impacts continues to be debated.[3]

The 'dependency' framework to explain environmental degradation in tropical agriculture centers on the role of export crop production. There are two main approaches, one based on analysis of the production process, while the other focuses on the role of the state. These two models of export stimulus and environmental decay can certainly help in developing an understanding of the dynamics of resource degradation in Amazonia, but they do not constitute a complete analysis. It is important to recognize that Amazonian beef is not an export product in the usual sense of the term. Although Amazonian development policy states that ' . . . Beef (from) Amazonia should be oriented fundamentally toward export markets . . .' (MINTER, 1974), in fact, cattle were only occasionally exported to Surinam (via boats from Marajo) and walked or trucked in small numbers across the Venezuelan border. Indeed, the Federation of Exporters of the state of Para reported that in the years documented by their records, beef generated only an annual average of $44,000 compared to the $33,000,000 of export revenues from Brazil nuts (FIP, 1977). Amazonia itself remains a net meat importer. Roughly 40% of the animals slaughtered in the Para abattoirs in the late 1970s were trucked from Goias (Hecht, 1982a). Thus, strictly speaking, Amazonian beef cannot be considered an export commodity, in spite of hopes to the contrary.

The first export-oriented explanatory model argues that development occurs under the discipline of international commodity prices, which demand that exports be produced as intensively and efficiently as possible. Therefore, agronomic technologies with high productivities are employed; they are generally mechanized and imply the use of large amounts of fertilizers, pesticides and herbicides, and thus are capital-intensive. These methods can generate direct environmental effects, such as compaction, and indirect effects, like water contamination and poisoning of fauna.

If the relationship of capital investment to employment and output is analyzed for eastern Amazonia, cattle ranching is more capital intensive than is industry per job created or per unit of output (Mahar, 1979; Hecht, 1982a). Given the high levels of capital investment, the first export paradigm — a highly technical production process — might appear to apply to the eastern Amazon area, particularly since the use of mechanical clearing is fairly widespread and becoming more so. Forest conversion to agriculture and pasture with machinery in the humid tropics has been shown to undermine the productivity of soil resources and to reduce yields (Seubert, Sanchez and Valverde, 1977). Mechanical deforestation is also substantially more expensive than is manual (Toledo and Serrao, 1982). I have argued elsewhere (Hecht, 1982a) that mechanical clearing on large ranches is related to the desire to minimize the use of human labor on ranches for a variety of compelling reasons including public health, fear of

squatters, violence and difficulty in controlling huge work teams. The capital intensity of eastern Amazonian cattle operations, however, is not reflected in the actual process of animal production *per se* since the technologies are quite primitive. What makes cattle ranching in Amazonia capital intensive is the very high barriers and infrastructure costs, not active investment in production technology.

The second model of the role of export production concludes that state subsidies (such as tax credits) and high international beef prices make it possible for landowners to make profits in spite of inefficient production organization and unsound land practices. This model has been applied to Central American livestock (Nations, 1980). In Central America, pasture productivity declined because of poor management and for ecological reasons, but not in a manner that completely put land out of production, as often occurs in Amazonia. Thus, animals can still be stocked in very low numbers while farmers expand grasslands into new areas to serve the international demand.

This approach contains some persuasive arguments, since the role of tax incentives and the pattern of land distribution in Amazonia are somewhat analogous to the case of Central America. But, there are several differences that make the two areas incommensurable. First, as noted, the price of beef is controlled, at least through gentlemen's agreements, in Brazil, making livestock profitability marginal even under the best of circumstances (Lattimore and Schuh, 1979). Livestock production in the Amazon is far more expensive than in other areas of the country (*O Globo*, 1980; *Conjuntura Economica*) and is usually not profitable on improved pastures even with extensive subsidies. Finally, Amazonian pastures generally go completely out of production in 10 years, a crucial difference between the Amazonian and Central American situation. Moreover, Brazilian beef has never been as closely integrated with international markets as Central American production.

In technology evaluation, the 'inappropriate technology' model argues that environmental problems result when well-intentioned planners mistakenly recommend technologies that for cultural or ecological reasons, generate resource degradation. The difficulties that occur are perceived as simple technological problems that can be resolved with a 'technological fix.' Such a point of view does have some validity in eastern Amazonia, in that the pasture species initially used were not well adapted to the low soil levels, and subsequent introductions, though more tolerant of the soil conditions, have been bothered by insect attack (i.e., *Brachiaria humidcola*). But the question really goes beyond the issue of better cultivars, since the structure of the pasture ecosystem itself very well may be inappropriate to the region (Hecht, 1982; Fearnside, 1980; Goodland, 1980). The more central issue is why certain land uses and technologies are promoted over other alternatives. I have argued in this article that ranching served important political and ideological functions, and that these, rather than varieties of *Panicum*, are what underlie the choice of pasture ecosystems for Amazonia, and their instability.

The environmental degradation associated with pasture development in eastern Amazonia is best understood as a consequence of the role of land in inflationary economies, the traditional function of livestock as a means of acquiring large areas (and the institutional rents associated with them), the stimulating effect of the physical opening of the agricultural frontiers on certain industrial sectors of the economy, and the role of large government subsidies in the creation of land markets and speculation in the Brazilian Amazon. The expansion of ranching through tax breaks, fiscal incentives and road development generated enormous untaxed capital gains for certain groups. Acquisition of land was the vehicle for capturing direct and indirect state subsidies. The productivity of the land became secondary because the land itself was the commodity. Due to the peculiarities of state subsidies, a radical disjuncture between the value of land for production and its value for exchange was created. If the productivity of the land itself has little importance, cautious land management becomes irrelevant, and environmental degradation is the inevitable result.

NOTES

1. Thompson (1965), p. 288.

2. The rephrasing of the environmental question within the context of social dynamics has recently been dealt with in volumes such as Hewitt (1984), and Redclift (1984). *Ecodevelopment*, a periodical edited by Ignacy Sachs, also addresses these questions.

3. The effect of deforestation on global climate and the hydrology of the major rivers is quite controversial. In terms of the global climate question, the issue centers on the contribution of deforestation to global CO_2 balances, and to the local atmospheric contribution of biotic 'pumping' of water vapor. The debate in the CO_2 question revolves around the quantities of

CO_2 released via deforestation and its fate: whether in fact the C released through deforestation (between 1.8×10^{15} and 4.7×10^{15} g in 1980 according to Woodell *et al.*, 1983) is released and stays mainly in the atmosphere, or whether alternative oceanic or organic sinks (vegetation, soil, organic matter) are absorbing substantial amounts (cf. La Marche *et al.*, 1984, Olsen, 1983; or Clarke, 1982). The controversy, not surprisingly, is linked to differences in data bases, methods and epistemologies, as well as a fairly high degree of uncertainty about carbon flux from particular sinks.

The contribution of evapo-transpiration from the vegetation to the atmosphere is thought to have important effects on weather patterns. According to Salati and Vose (1984) and Salati *et al.* (1979) roughly 50% of the rainfall is transpired back into the atmosphere, of which 48% falls again as rain. This mass of water indicates a very high recycling rate. In a study of two watersheds near Manaus, the following numbers on evapo-transpiration were obtained:

	Site 1	Site 2
Interception and evaporation	18.7	25.6
Transpiration	62.0	48.5
Runoff	19.3	25.9

South American atmospheric circulation patterns suggests some of this water vapor in the Amazon Basin is exported into the Paraguayan Chaco and to the Central Brazilian Plateau and, thus, large-scale deforestation in these areas could have serious effects on climate in these areas.

Water cycles presumably must also be affected by large-scale deforestation and gentry and Lopez-Parodi (1982) found a statistically significant increase in the peak flows at Iquitos from 1962 to 1978. The results of this study have been disputed by Nordin and Meade (1982) because of the high degree of variability of the peak flows, and the fact that the 'hundred year flood' occurred prior to significant deforestation. The types and magnitude of changes relate not only to the timing and volume of flow, but also to their impacts on the food supply of the herbivorous fish who feed on the riparian vegetation during high flood periods. Short intense floods may not permit adequate feeding times or reproduction.

REFERENCES

Alvim, P. T., 'Perspectivas de producao agricola na Regiao Amazonica,' *Interciencia*, Vol. 3, (1978), pp. 243–251.

Alvim, P. T., 'Agricultural production potential of the Amazon Region,' in F. Barbira-Scazzochio (Ed.), *Land, People and Planning in Contemporary Amazonia* (Cambridge: Center for Latin American Studies, Cambridge University Press, 1980).

Aragon, L., 'Migration to Northern Goias,' Ph.D. thesis (East Lansing: Michigan State University, 1978).

Bacha, E. L. 'Issues and evidence on recent Brazilian economic growth,' *World Development*, Vol. 5, No. 2 (1977), pp. 47–67.

Bandy, D. and P. A. Sanchez, 'Continuous crop production on acid soils in the Peruvian Amazon,' paper presented at a Workshop on Management of Low Fertility Acid Soils, University of Surinam (Paramaribo: Surinam, 1981).

Belassa, B., 'Incentive policies in Brazil,' *World Development*, Vol. 7, No. 2 (1979), pp. 1023–1042.

Bergsman, J., *Brazil's Industrialization and Trade Policy* (New York: Oxford Press, 1970).

Brown, S. and A. Lugo, 'Storage and production of organic matter and their role in the global carbon cycle,' *Biotropica*, Vol. 14 (1982), pp. 161–179.

Bunker, S., 'Power structures and exchange between government agencies in the expansion of the agricultural sector in Para,' *Studies in Comparative and International Development*, Vol. 14, No. 1 (1979), pp. 56–76.

Clarke, C., 'The economics of overexploitation,' *Science*, Vol. 181 (1974), pp. 630–634.

Clarke, W. C., *Carbon Dioxide Review* (New York: Oxford University Press, 1982).

Cochrane, T. and Sanchez, P. A., 'Land resources of the Amazon Basin,' in S. B. Hecht (Ed.) *Land Use and Agricultural Research in the Amazon Basin* (Cali, Colombia: CIAT, 1982), pp. 137–211.

Conjuntura Economica (Rio de Janeiro: Fundagão Getulio Vargas).

Coordenadora de Assistencia Technica Integral, *Normas Para Manejo de Pastagens, Boletim Tecnico 81* (Belem, Brazil: 1974).

Davis, S., *Victims of the Miracle* (Cambridge: Cambridge University Press, 1977).

Durham, W., *Scarcity and Survival in Central America* (Berkeley: University of California Press, 1980).

Eckholm, E., *Down to Earth* (London: Pluto Press, 1982).

Ellen, R., *Environment, Subsistence and System* (Cambridge: Cambridge University Press, 1982).

Evans, Peter, *Dependent Development: The Alliance of Multinationals, the State, and Local Capital in Brazil* (Princeton: Princeton University Press, 1979)

Falesi, I., *Ecosistema de Pastagem Cultivada na Amazonia Brasileira, Boletim Tecnico* 1, (Belem, Para: EMBRAPA, 1976).

FAO/ECLA (United Nations Food and Agricultural Organization/Economic Commission on Latin America), *Livestock in Latin America* (Rome: FAO, 1964).

Fearnside, P., 'Estimation of carrying capacity for human settlement of the TransAmazon Highway colonization area of Brazil,' Ph.D. thesis (University of Michigan, 1978).

Fearnside, P., 'Effects of cattle pastures on soil fertility in the Brazilian Amazon: Consequences for beef production sustainability,' *Tropical Ecology*, Vol. 21, No. 1 (1980), pp. 122–137

Feder, E., 'Lean cows, fat ranchers: A study of the Mexican beef industry,' manuscript (Berlin: 1979).

FIP (Federacao de Industrias do Para), *Para Exportacao* (Belem: FIP, 1977).
Fishlow, A., 'Brazilian size distribution of income,' *American Economic Review*, Vol. 62, No. 2 (1973), pp. 391–402.
Foweraker, J., *The Struggle for Land* (Cambridge: Cambridge University Press, 1980).
Franke, R. and B. Chasen, *Seeds of Famine* (New Jersey: Allanheld, Osmun, 1980).
O Globo, 5 January 1980.
Gentry, A. and J. Lopez-Parodi, 'Deforestation and decreased flooding in the Upper Amazon,' *Science*, Vol. 210 (1980), pp. 1354–1356.
Gomez-Pompa, A., C. Vasques-Yanes and S. Guevara, 'The tropical rain forest: A non-renewable resource,' *Science* Vol. 177 (1972), pp. 762–765.
Goodland, R. 'Environmental ranking of development projects in Brazil,' *Environmental Conservation*, Vol. 7, No. 1 (1980), pp. 9–25.
Goodland, R. and H. Irwin, *Red Hell to Green Desert?* (Amsterdam: Elsevier, 1975).
Hardin, G., 'The tragedy of the commons,' *Science*, Vol. 162 (1968), pp. 1243–1248.
Harvey, D., 'Population, resources and the ideology of science,' *Economic Geography*, Vol. 50, No. 3 (1974), pp. 256–278.
Hecht, S. B., 'Cattle ranching in the Brazilian Amazon: Evaluation of a development strategy,' Ph.D. thesis (Berkeley: University of California, 1982a).
Hecht, S. B., (Ed.), *Land Use and Agricultural Research in the Amazon Basin* (Cali, Colombia: CIAT, 1982b).
Hewitt, D. *Interpretations of Calamity* (Boston: Allen & Unwin, 1984).
Hoskins, M., 'Musings on technology transfer,' OTA Workshop (Shepards Ford, VA: 1982).
Ianni, O., *A Luta Pela Terra* (Petropolis: Vozes, 1978).
InterAmerican Development Bank (IADB), *Annual Reports* (Washington, D.C.: IADB, 1971–76).
Janzen, D., 'Tropical Agro-ecosystems,' *Science*, Vol. 182 (1973) pp. 1213–1218.
Jarvis, L., 'Livestock in Latin America,' Mimeo. (Berkeley, CA: 1984).
Klinge, H., E. Rodrigues Brunig, and E. J. Fittkau, 'Biomass and structure in a Central Amazonian rainforest,' in F. Golley and E. Medina, (Eds.), *Tropical Ecological Systems*. (New York: Springer-Verlag, 1975), pp. 115–122.
Knight, P. T., *Brazilian Agriculture, Technology, and Trade* (New York: Praeger, 1971).
Kohlepp, G., 'Erschliessung und Wirtschaftliche Inwertsetzune Amazoniens. Entwicklungsstrategien Brasilianischer Planungs-froltik und Privater Unfernehmen,' *Geografische Rundschau*, Vol. 30, No. 1 (1978) pp. 2–13.
Koster, H., E. J. Kahn and R. Bossert, *Programa e Resultados Preliminarios dos Estudos de Pastagems na Regiao de Paragominas Para, e o Nordeste de Mato Grosso* (Belem, SUDAM/IRI, 1977).
La Marche, V., D. Graybill, H. Fritts and M. Rose, 'Increasing atmospheric carbon dioxide: The evidence for growth enhancement in natural vegetation,' *Science*, Vol. 225 (1984), pp. 1019–1021.
Lamartine-Noguero, F. de., *A Agropecuaria e o Processo de Desenvolvimento da Amazonia* (Belem: BASA/MINTER, 1969).
Lattimore, R. G. and G. D. Schuh, 'Endogenous policy determination: The case of the Brazilian beef sector,' *Canadian Journal of Agricultural Economics*, Vol. 27, No. 2 (1979), pp. 1–16.
Leff, N. H., 'Export stagnation and autarkic development in Brazil,' *Quarterly Journal of Economics* (May 1967), pp. 286–301.
Mahar, D. J., *Frontier Development Policy in Brazil: A Study of Amazonia*. (New York: Praeger, 1979).
Malan, P. S. and R. Bonelli, 'The Brazilian economy in the 70s: Old and new development,' *World Development*, Vol. 5, Nos. 1/2 (1977), pp. 19–37.
Malthus, T., *Essay on Population* (Harmondsworth: Penguin, 1970).
Mamdami, M., *The Myth of Population Control* (New York: Monthly Review Press, 1972).
Martine, G., 'Expansao e retracao de *emprego na fronteira agricola*,' in N. Gligo and C. Mueller (Eds.), (Brasilia: University of Brasilia, 1982).
Milton, M. and M. Farvar, *The Careless Technology* (St. Louis: Washington University Press, 1968).
MINTER (Brazil, Ministerio do Interior), *Programa Nacional de Desenvolvimento* (Brasilia: MINTER, 1975).
Molion, L. C., 'A climatic study of the energy and moisture fluxes of the Amazonas Basin with considerations of deforestation effects,' Ph.D. thesis (1975).
Moore, B., *The Social Origins of Dictatorship and Democracy* (New York: Beacon, 1968).
Moran, E., *Developing the Amazon* (Bloomington: University of Indiana Press, 1981).
Mueller, C. and N. Gligo, *Espansao da Fronteira e Meio Ambeinte* (Brasilia: University da Brasilia, 1982).
Murdoch, W., *The Poverty of Nations* (Baltimore: Johns Hopkins, 1980).
Myers, N., *Conversion of Moist Tropical Forests* (Washington, D.C.: National Academy of Sciences, 1980).
Nations, J., Report to the Tinker Foundation (1980).
Nicolaides J., P. Sanchez, D. Bandy, J. Villachica, A Coutu and C. Valverde, 'Crop production systems in the Amazon Basin,' in Moran (Ed.), *The Dilemma of Amazonian Development* (Boulder: Westview Press, 1983).
Nordin, C. and R. H. Meade, *Science*, Vol 215 (1982), p 426.
Nye, P. and D. Greenland, *The Soil Under Shifting Cultivation* (Farnham Royal, Bucks, UK: Commonwealth Agricultural Bureau, 1960).
O'Donnell, G., *Modernization and Bureaucratic Authoritarianism* (Berkeley: University of California Press, 1979).
Office of Technology Assessment (OTA), *Technologies for Sustaining Tropical Forests* (Washington, D C.: OTA, 1984).
Olsen, G., 'Energy storage and the balance between producers and decomposers,' *Ecology*, Vol. 44 (1968), pp. 322–331.
Olsen, G., Manuscript cited in Woodell *et al.* (1983).
Parsons, J.J, 'Forest to pasture: Development or

destruction?' *Revista de Biologia Tropical*, Vol. 24, No. 1 (1976), pp. 121–138.

Pires, J. M. and G. T. Prance, 'The Amazon forest: A natural heritage to be preserved,' in G. T. Prance and T. Elias, (Eds.), *Extinction is Forever* (Bronz: New York Botanical Garden, 1977).

Programa Nacional de Desenvolvimento (PND) (Brasilia: MINTER, 1975).

Pompermeyer, M. J., 'The state and frontier in Brazil,' Ph.D. thesis (Stanford University, 1979).

Possio, G., 'An economic analysis of cattle ranching in Amazonia,' M.S. thesis (Berkeley: University of California, 1984).

Redclift, M., *Development and the Environmental Crisis* (New York: Methuen, 1984).

Salati, E., A. Dall Olio, E. Matsui and S. R. Gat, 'Recycling of water in the Amazon Basin: an isotope study,' *Water Resources Research*, Vol. 15, No. 5 (1979), pp. 1250–1258.

Salati, E. and T. Lovejoy, 'Principitating change in Amazonia,' in. E. Moran (Ed.), *The Dilemma of Amazonian Development* (Boulder: Westview Press, 1983).

Salati, E. and Shubart, 'Natural resources for land use in the Amazon,' in S. B. Hecht (Ed.), *Land Use and Agricultural Research in the Amazon Basin* (Cali, Colombia: CIAT, 1982b).

Salati, E. and P. Vose, 'Amazon forest, a system in equilibrium,' *Science*, Vol. 225, No. 4658, pp. 129–137.

Sanchez, P. A., *Properties and Management of Tropical Soils* (New York: Wiley Interscience, 1976).

Sanchez, P. A., 'Soil fertility and conservation considerations for agro-forestry systems in the humid tropics of Latin America,' in H. Mongi and P. Hucksley (Eds.), *Soils Research in Agro-Forestry* (Nairobi: ICRAF, 1979).

Sanchez, P. A., D. Bandy, J. Villachica and J. Nicolaides, 'Amazon soils management for continuing crop production,' *Science*, Vol. 211 (1982), pp. 821–827.

Santos, A., E. Odeao de Novo and V. Duarte, *Degraducao de Pastagens na Amazonia*. Belem: Relatorio do Projeto INPE/LANDSAT, 1979).

Santos, R., 'Sistema de propriedade e relacoes de trabalho no meio rural Paraense,' in Monteiro de Costa, (Ed.), *Amazonia: Desenvolvimento e Occupacao* (Rio de Janeiro: IPEA/INPES, 1979).

Sawyer, D., 'Peasants and capitalism on the Amazonian frontier,' Ph.D. thesis (Harvard University, 1979).

Schmink, M., 'Land conflicts in Amazonia,' *American Ethnologist*, Vol. 9, No. 2 (May 1982), pp. 341–357.

Sen, A., *Poverty and Famines* (Oxford: Clarendon Press, 1981).

Serrao, A., I Falesi, J. B Vega, and J. F. Teixeira 'Productivity of cultivated pastures on low fertility soils of the Brazilian Amazon,' in P A. Sanchez and L. E. Tergas, (Eds.), *Pasture Production in Acid Soils of the Tropics* (Cali, Colombia: CIAT, 1979).

Seubert, C. E., P. A. Sanchez and C. Valverde, 'Effects of land clearing methods on the soil properties and crop performances on an ultisol of the Amazon jungle of Peru,' *Tropical Agriculture*, Vol. 54 (1977), pp. 307–321.

Silva, L. F., *Influencia do Manejo de un Ecosistema nas Propriedades Edaficas dos Oxisols de Tabuleiro* (Itabuna, Bahia: CEPLAC, 1978).

Smith, N. J., 'TransAmazon Highway: A cultural and ecological analysis of settlement in the humid tropics,' Ph.D. thesis (Berkeley: University of California, 1976).

Souza-Martins, J., *O cativeiro da Terra* (Sao Paulo: Libraria Editora Ciencias Humanas, 1980).

Souza-Martins, J. (1983).

Stepan, A., *The Military in Power* (Princeton: Princeton University Press, 1968).

Stepan, A., *Authoritarian Brazil* (Princeton: Princeton University Press, 1973).

SUDAM (Superintendencia de Desenvolvimento da Amazonia), *O Problema da Occupacao Economica da Terra* (Belem: SUDAM, 1974).

Sunkel, O., Estilos de Desarrollo e el Medio-Ambiente (Brasilia: University of Brasilia, 1982).

Tardin, A. T., A. dos Santos, E. M. Moraes-Novo and F. L. Toledo, *Relatorio Atividades do Projeto SUDAM/INPE* No. 1034, NTE (Sao Jose dos Campos, Brazil: INPE, 1977).

Tardin, A. T. *et al.*, *Levantemento de Areas de Desmatamento na Amazonia Legal Atraves de Imagens do Satelite LANDSAT*, INPE Report No. 411-NTE/142 (Sao Jose dos Campos, Brazil: INPE, 1979).

Taylor, L., E. Bacha, E. Cardoso and F. Lysy, *Models of Growth and Distribution for Brazil* (New York: Oxford Press, 1980).

Thompson, E. P., *Making of the English Working Class* (New York: Monthly Review, 1965).

Tietzel, J. and R. Bruce, 'Fertility of pasture soils in the wet tropical coast of Queensland,' *Australian Journal of Experimental Agriculture and Animal Husbandry*, Vol. 12 (1972), pp. 49–54.

Todaro, M. *Economic Development in the Third World* (London: Longman, 1977).

Toledo, J. and A. Serrao, 'Pasture and animal production in Amazonia,' in S. B. Hecht (Ed.), *Land Use and Agriculture Research in the Amazon Basin* (Cali, Colombia: CIAT, 1982).

Watts, M., *Silent Violence* (Berkeley: University of California Press, 1983).

Wood, C. and M. Schmink, 'Blaming the victim: Small farmer production in an Amazon colonization project,' *Studies in Third World Societies*, Vol. 7 (1979), pp. 77–93.

Wood, C. and J. Wilson, 'The role of the Amazon frontier in the demography of rural Brazil,' in C. Wood and M. Schmink, *The Frontier Development in the Amazon* (Gainsville, FL: University of Florida Press, 1983).

Woodell, G. *et al.*, 'Global deforestation: Contribution to atmospheric carbon dioxides,' *Science*, Vol. 222, No. 4628 (1983), pp. 1081–1086.

World Bank, *Forestry Sector Paper* (Washington D.C., World Bank, 1978).

GLOSSARY

BASA	Banco da Amazonia
cerrado	a savanna type of vegetation, a grassland with an important woody component
EMBRAPA	Empresa Brasiliera de Agropecuaria. The Ministry of Agriculture network of research institutions
INCRA	National Institute for Colonization and Agrarian reform
Mata fina	a lower biomass forest that often occurs near the transition to cerrado, or along the 1,200 mm rainfall isohyet
MINTER	Ministry of the Interior
PIN	National Program for Integration
PDAM	National Program for Amazonian Development
PND	National Development Program
SPVEA	Superintendency for the Economic Valorization of Amazonia
SUDAM	Superintendency for Amazonia Development.