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Analysis

Land use and land cover dynamics in the Brazilian Amazon: an overview

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Abstract

This paper presents a theoretical discussion of processes linking land use decisions and land cover outcomes at household level, with an emphasis on small proceduers. Evidence from the literature substantiating the existence of domestic cycle phenomena is brought forward and interpreted for the Brazilian case. Also considered are the relative disposition of production factors in the frontier development process, implications for the exercise of political power, and relationships between land concentration and ecological change. The paper concludes with a discussion of traditional land use zonation models originating with Von Thunen, and considers their relevance for the process of frontier development and tropical deforestation.

Keywords: Land use; Land cover; Brazilian Amazon; Zonation models; Frontier development; Tropical deforestation; Small producers

1. Introduction

Changes in land cover represent significant threats to ecosystem sustainability, particularly when naturally vegetated forms give way to human use. Such conversions often reduce the availability of energy, water, and nutrients to ecosystems, facilitate the invasion of exotic species, and generally speed-up natural change processes (Ojima et al., 1994). Besides inducing on-site impacts, the expansion of urban and agricultural areas into the natural landscape also leads to externality effects beyond the development fringe (Douglas, 1994). The purposeful conversion of natural vegetative cover is driven by the demand for land. In the agrarian setting of the tropical frontier, land is a key production factor, and the demand for land is a derived demand affected by both product and factor prices (Ozorio de Almeida, 1992; Walker, 1993). The demand for land leads to productive *land use*, the dedication of the land factor to particular forms of agricultural production; these uses, in turn, require groundcover manipulations, such as deforestation. The purpose of this paper is to address land use dynamics at household level, particularly among small producers, and to situate these dynamics within broad-scale, structural circumstances. To this end, we extend the household econ-

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omy model of Chayanov (Ellis, 1993) to dynamic cropping decisions in the Brazilian Amazon. Our extension involves a synthesis of household production theory and notions of domestic cycle taken from anthropology and other disciplines.

It is necessary to draw a distinction between small producers, typically migrants, and indigenous peoples practicing long-fallow agriculture. The farming systems of indigenous people, practiced at low population densities and with specialized ecological knowledge, are thought to be relatively *sustainable*, [1] as compared to the practices of migrants (Vayda, 1979; Hames and Vickers, 1983; Dove, 1986; Posey and Balée, 1989; Moran, 1990; see Simmons, 1995 for an alternative viewpoint). Small producers have been held responsible—often unfairly—for tropical deforestation, particularly in the model of *invasive forest mobility* (Walker, 1993) used by many to explain observed forest losses. In this oft-told story, small farmers follow roads into primary forest and engage in shifting cultivation. As soil fertility declines, they move to new parts of the forest made accessible by the roads in a never-ending cycle of forest destruction and soil degradation (see Walker and Smith, 1993).

Many discussions on Brazilian deforestation emphasize the roles played by urban capital, in-migration, and land concentration. As has been noted for the case of Brazil, deforestation in the recent past is accounted for mainly by large ranching operations attracted to the region by government policy (Browder, 1988; Mahar, 1988; Serrão et al., 1996). Nevertheless, it is estimated that Amazonia is home to perhaps 50 000 cattle operations at all scales of operation (Hecht, 1992), and strong tendencies toward pasture conversion have been observed among small producers (Homma et al., 1994). Given such evident trends in land use and the apparent profitability of ranching even for relatively modest operations (Mattos and Uhl, 1994), the component of Amazonian deforestation attributable to small producers could increase, particularly with the abandonment of incentive programs by SUDAM. In at least one Amazonian state, Rondonia, current deforestation seems largely driven by the pace of immigration of mostly small producers, and areas devoted to cattle grazing are growing; recent rapid growth of pasture in Amazonia has been observed among small producers unlikely to have received any government assistance (Schneider, 1995).

The paper is organized as follows. Section 2 presents a stylized version of the so-called cause–cover relationship used in describing the driving forces of land cover change (Turner et al., 1994). This is followed by a discussion focusing on the development cycle of domestic groups. The anthropological foundation is considered, and contemporary applications to household resource management are addressed. Section 2 also discusses the relationships between land concentration and ecological change. Section 3 broadens the analysis scale by considering theoretical approaches to regional development. Bid-rent-oriented theories of land use are interpreted in light of on-the-ground circumstances in the Brazilian Amazon. Section 4 concludes the paper by noting the indissoluble link between social and ecological conflict in the process of frontier development.

2. Land cover / land use dynamics

Fig. 1 presents in general terms the process of land cover/land use interaction (Turner et al., 1994). Here, the driving forces of land cover change are divided into (1) a particular agent (i.e., a small producer household) and (2) external economic factors. Farm systems typically comprise a diversity of land uses on individual properties; these systems require human interventions leading to alterations in vegetation that are the *proximate sources* of land

[1] Sustainability and sustainable development are key concepts in discussions on environmental degradation in the tropical country context; unfortunately, they are not well defined. We choose not to engage this discourse, however, and rely instead on a largely intuitive notion of sustainability. For farming systems, sustainability implies the 'reproducibility' of the social unit through adequate economic performance. Also informing our use of the term is an ecological dimension derivative from the agroforestry literature. In particular, it is assumed in our discussion that woody vegetation, by and large, is less demanding of soil resources, exerts reduced biodiversity impacts, particularly on faunal species, and generates fewer fire-related externalities than other ground covers used by farmers, such as pasture (e.g., Arnold, 1983). For such reasons, many have argued that agroforestry enhances sustainability in tropical areas.

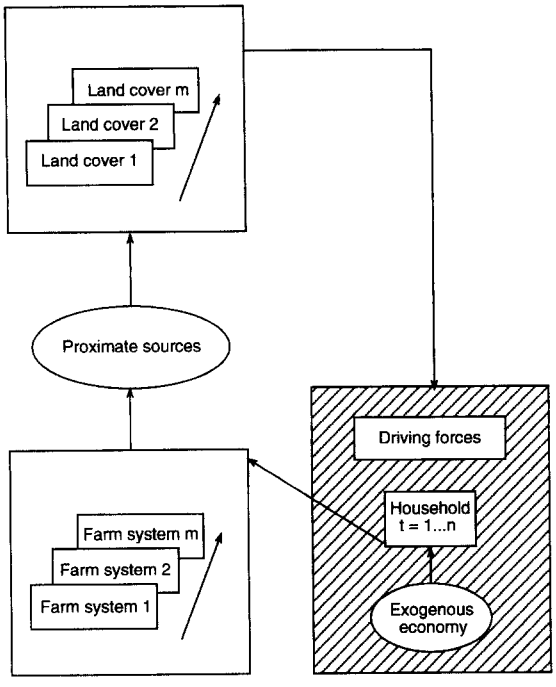

Fig. 1. Cause–cover relationship. Adapted from Turner et al. (1994).

cover change (Turner et al., 1994). We argue that with ongoing development of the household, and with changes in their strategic responses to evolving economic conditions, farm systems also change, and as a consequence so does land cover. In addition, land cover itself can ultimately affect a household's economic status by restricting crop choices through environmental degradation. This interactive process may be illustrated with an example taken from the Brazilian case. Land use for annual crop production, with proximate sources of vegetative change arising from slash-and-burn technology, leads to a particular land cover of secondary forest (and shrub formations) in various age classes. With increases in the family labor supply, the household structure changes, and new farming systems may be implemented, such as ranching. Ranching, in turn, leads to modified forms of herbaceous land cover that result from altered farm activities. In the long-run, pastures could lose productivity, and repeated burnings could damage soil structure to the point that the household may only be able to grow a crop with low nutrient demands like cassava.

Financial circumstances of the family affect this process through all stages, since farm system choice is in part a function of available capital. In the early stages of farm establishment, the endowment of the family plays a significant role in the starting point of a property's land cover trajectory (Bonnal et al., 1993). Subsequent changes in economic conditions, both internal and external to the household, continue to condition land use decisions and hence the household's land cover dynamic. To the extent that initial financial endowments ensure economic well-being, such advantages are perpetuated, and associated land covers will reflect this. On the other hand, poor farmers may accumulate and find themselves able to switch to highly capitalized farm systems using modern inputs and technology. Of course, the household economy could worsen, leading to farm failure and possible abandonment of fields to succession. Wealth accumulation (including land improvements, farm implements, and consumer durables) and the availability of financial resources are determined by both internal household dynamics, especially growth of family workforce, and conditions in the external economic environment.

In the Chayanov framework, small-producer land holdings grow with additions to the household workforce. This dynamic is largely supply-side-driven, with labor increments expanding the scale of production; output equilibria are given by marginal utility valuations *vis-à-vis* production possibilities involving crops and *leisure*, in the absence of markets (Ellis, 1993). Household production theory links family utility to production decisions and land use via markets for both labor and products (Singh et al., 1986). We posit production dynamics at household level in which the family resource base evolves *together* with objectives of household members (Watkins et al., 1993). In particular, as the internal balance of labor power and consumption change, so does the disposition toward risk-bearing and *saving* through specific types of crop choices (e.g., pasture for cattle), leading to alterations in crop selections and dynamic land allocations reflecting the life cycle stages of the household head and domestic group (Modigliani and Brumberg, 1954). We posit this model on the basis of research investigating links between household structure and resource management behavior.

2.1. Development cycles and resource use strategies

Early anthropological work on internal household dynamics addressed relationships between domestic group structure and institutions such as those governing patterns of inheritance (e.g. Goody, 1962). More recently, Wilk (1984) has described structural adaptations at household level to increasing population pressures in Belize, presumably the outcome of an intergenerational process of land use intensification. Wilk argues that reduced land availability necessitates crop diversification, which greatly complicates labor applications. The social response is that independent dwelling units form complex household arrangements in order to better organize production tasks. In addition, Wilk refers specifically to risk attitudes as a function of age of household head and links this to choice of rotation cycle. Anthropological research on domestic cycle phenomena has tended to address those aspects of family structure interpretable as endogenous responses to institutional variation across groups and to long-run demographic processes, such as land intensification. In a similar vein, Bilsborrow (1987) and Bilsborrow and Geores (1992) synthesize Boserup's notion of agricultural intensification (Boserup, 1965) with demographic behavior at household level (e.g., Davis, 1963) to develop a concept of phased response to increasing population pressure on land. The responses are hypothesized to arise in sequence from economic/technical adaptations (or Boserupian), to migration, to changed reproductive behavior. Reproductive responses, in particular, may require intergenerational time-spans. Bilsborrow explicitly addresses developmental sequences of individual household units, as opposed to cross-sectional variations in household structure across different communities (see also Wood, 1981).

Recent research suggests direct linkages between household structure and the economic activities of small producer households in a number of tropical countries. Relationships between household types and a broad suite of economic strategies, including both on and off farm labor, have been noted (e.g., Stonich, 1993; Leinbach and Smith, 1994), as have links between household structure and choice of farming system (CAT, 1992; Bonnal et al., 1993; Bonnal and Zoby, 1994; Zweifler et al., 1994) and diversification of farm activities (Brasil and McCracken, 1993; Stonich, 1993). The household context of farm consolidation in a new frontier has been addressed as well (Lisanky, 1990; Sydenstricker Neto and Vosti, 1993), as has the impact of resource exhaustion and economic necessity on farming system choice, independently of household structure (Stearman, 1983; Vosti and Witcover, 1993, N.D.). General patterns of farming system evolution at household level have also been recognized (Ortiz, 1984; Homma et al., 1993), although linkages between household structure and landscape pattern remain largely implicit in the discussions to date.

Leinbach and Smith (1994) explicitly address the *family life cycle* as it relates to involvement in off-farm employment. They find that young families, with high consumption demands relative to labor supply, tend to depend more heavily on local labor markets than more established units. In addition, a land ownership effect is in evidence with larger holdings leading to less reliance on off-farm income. Leinbach and Smith (1994, pp. 293–294) note that the "life cycle... provides a cyclical process in which differing household requirements need to be fulfilled through access to more resources," but they do not apply this insight to the demand for land. Stonich notes that poor families confront challenges through a domestic structure she refers to as the *elastic household*, whose members respond by circular and permanent migrations and by rapid economic adaptation (Stonich, 1993, p. 126). Although the family may endure prolonged periods of disruption, risk is spread both geographically and through a variety of income-earning activities.

Bonnal et al. (1993) consider the link between farming systems choice and the life cycle stages of domestic groups (see also Bonnal and Zoby, 1994). Using survey research on small producers in the State of Goias, Brazil, Bonnal et al. (1993) classify 89 properties into 9 system types using factor analysis. Bonnal et al. (1993) argue that the process of accumulation is a function of the availability of productive resources in the household, especially labor power, and that this bears a relationship to life cycle stage; they also indicate the importance of initial resource endowment. Bonnal et al. (1993) describe system evolution as a discernible series of stages, or *trajectories*, involving subsistence opera-

tions, herd formation, and dairy farming. These researchers note that late stages of the life cycle may return the operation to an early system, given contraction in the family work force. Zweifler et al. (1994) describe the evolution of agricultural landscapes in the Dominican Republic, and identify a household-level process of farming system change. In particular, until recently young families began farming in one of the study areas by growing annual food crops, which served as a "stepping stone for building a more stable and diversified system" (Zweifler et al., 1994, p. 49).

Brasil and McCracken (1993) address the relationship between family *type* and diversification of agricultural activities on Marajo Island, Brazil. Nuclear families with young children show high dependency, reduced workforce, and relatively diverse economic activities. *Consolidated* families (containing only adult, unmarried children) have a relatively large workforce, low dependency, and reduced diversity of extractivist and agricultural activity. Stonich (1993) also considers the diversification of activities among small producers. A young family with high dependency may spread risk over a number of activities, on and off the farm, but with economic success, the household economy presumably becomes more focused on a single, profitable activity, such as cattle ranching (Stonich, 1993, pp. 138–140). Sydenstricker Neto and Vosti (1993) describe a link between alterations in household and type of farming activity, suggestive of Stonich's concept of the *elastic household.* In particular, household decomposition occurs with adult male outmigration to settlement fronts where forest is cleared mainly by men. Later, the family reassembles on the newly created farm, and land preparation gives way to farming and complementary activities engaged in by the various family members. The entire process of farm creation may take up to 10 years in Amazonian settlement areas, and for small producers is typically dependent on available family labor (Lisanky, 1990).

Although this discussion focuses on the link between household structure and farm activities, microeconomic theory suggests the importance of external conditions in farming system choice. Product price movements play an obvious role in land use decisions, as do quality of the resource base and public infrastructure; under slash-and-burn technology, soil fertility depletion alone may cause changes in farming systems. Homma et al. (1994) present data linking price dynamics and production magnitudes (for black pepper) in Tomé-Açu, State of Pará, Brazil. Vosti and Witcover (N.D., 1993) argue that farms shift production systems to take advantage of new and profitable opportunities, or as an act of desperate economic necessity to avoid bankruptcy. In a study of small producers in Minas Gerais, Brazil, for the period 1979–1984, Vosti and Witcover (1993, p. 16) conclude that system switches were largely the result of economic necessity. Despite their market orientation, Vosti and Witcover (N.D.) speculate that 'life-cycle' stage affects household decision-making, and argue that soil fertility decline narrows the household's range of farming system choices through time. Vosti and Witcover (N.D.) do not provide an explicit theoretical linkage between household development and farming system evolution.

2.2. Evidence in the State of Pará, Brazil

Recent research in the Brazilian Amazon (State of Pará) provides a detailed description of dynamic household–forest interactions (Centro Agro-Ambiental do Tocantins: CAT, 1992), which is consistent with our incorporation of risk and crop switching into the Chayanov framework. This schematic representation reflects what might be regarded as a central tendency for *successful* domestic cycle outcomes, and is not presented, in its original context, as the exclusive strategy for survival and accumulation in the region. The process begins with the arrival of a young family on a parcel of land containing virgin forest. At this early stage, the family possesses a high dependency ratio and few labor resources; presumably, its meager capital reserves are largely exhausted in the initial land purchase. The first crop selection involves time-tested annuals such as rice, corn, and beans, and the semi-annual, cassava. These crops provide a reliable subsistence, and lead to the creation of a rotation based system and stock of secondary forest.

As children age, the labor supply is enhanced and new ventures can be undertaken. At this stage, the family may accumulate sufficient capital to buy more land; if successful, land is cleared to pasture and several head of cattle are purchased. With continuing

additions to the family workforce and eventual participation in local labor markets by family members, the household is able to further augment investments in cattle. As presented in its original form, the cycle leads to increasing land values and the accumulation of family wealth in the long run. Associated with this felicitous outcome is an ongoing dynamic between land use and resident ecosystems. Loss of virgin forest—and associated biodiversity impacts—often occur at early stages of land settlement and dissipate with a growing stock of secondary forest (Homma et al., 1993). [2] Then, the traditional system of slash-and-burn agriculture persists to such time as household labor power is sufficient to create pasture from the stock of secondary forest, which gives way to herbaceous groundcover.

The land use trajectory indicated in the CAT scenario appears somewhat restrictive given the diversity of cropping systems observed in parts of the Brazilian Amazon. These often include full complements of annual crops, cattle and perennials (Homma et al., 1994; Walker et al., 1994). Accumulation, obviously, is not an inevitable outcome either, and many households remain at subsistence level throughout the domestic cycle, a status observed all too often in rural Brazil. Other households go through phases of accumulation and de-capitalization, with the outmigration of adult children and government failure to provide essential infrastructure. Field abandonments and farming system switches may occur with aging of the household head and contraction of family labor (see Lisanky, 1990). Such domestic cycle phenomena probably account for some proportion of the forest succession currently observed in the Brazilian Amazon (Uhl and Buschbacher, 1985; Buschbacher et al., 1988; Moran et al., 1994).

Farming systems can include stationary and evolutionary components simultaneously, and do not always demonstrate complete and irreversible movement toward pasture as suggested by the CAT scenario. Scatena et al. (1994) show that in a sample of fields consisting of secondary forest of differing ages, 23 percent are turned into pasture directly, while 6 percent are converted to some type of perennial. The remainder persist in rotational agriculture (at least over the short to mid-run), or they are abandoned entirely to uninterrupted successional processes. Increase in the stock of family labor facilitates plantation establishment of perennials which can be quite costly in terms of labor (Toniolo and Uhl, 1994). As with developing the infrastructure necessary to herd formation (e.g., fences), the implementation of an agroforestry component (i.e., perennials) is an investment decision since returns do not accrue immediately to the farming household (Etherington and Matthews, 1983; Walker et al., 1993).

Nevertheless, the CAT representation is consistent with long-run change processes in an important development front along the Transamazon Highway in the State of Pará, when interpreted as a system evolution from income (cf., annuals) to investment crops (cf., cattle and perennials). [3] In 1975, Homma (1976) observed in a sample of 96 small producers in the region a predominance of annual crops production. Average herd size was 1.4 animals, and average pasture area was 6.41 hectares, a little more than double the average rice area of 2.54 hectares (Homma, 1976). Subsequent field research in the same area (Walker et al., 1994) indicates a substantial amount of continued annual crop production, with an average rice area of 4.07 hectares (Homma et al., 1994). Involvement in investment crops, ne-

[2] A possibly misleading implication is that environmental impacts associated with deforestation end with the cessation of virgin forest clearance. Use of secondary forest requires fire, however. The slash-and-burn technology is complex and involves many different forms of fire (see Homma et al., 1993). Of course, continued virgin forest clearance can and does occur throughout the domestic cycle, given sufficient access to productive factors and appropriate household objectives.

[3] Some deferment is involved in realizing the gains from annual crops production, but *waiting* generally ends within the same year of site preparation and cultural treatments. Thus, annual crops may be regarded as constituting a form of income. Pasture creation requires substantial investment of labor power and other available resources in developing the infrastructure necessary for herd formation (e.g., fences), and returns are not realized for several years. Similarly, the implementation of an agroforestry component (i.e., perennials) into the farming system represents an investment, since returns do not accrue immediately to the household (Etherington and Matthews, 1983; Walker et al., 1993).

cessitating the development of property infrastructure and biomass stocks, has increased substantially, however. Average property herd size is now 35, and the average initial pasture of 6.3 hectares (given in the current sample of 132 producers) has grown to 37 hectares, over a period on average of 15 years. In addition, large plantations of cocoa, coffee, and pepper are in evidence, complementing the investment component represented by cattle ranching (Homma et al., 1994). Farm evolution processes similar to the CAT (1992) representation have been observed in Colombia (Ortiz, 1984) and Bolivia (Stearman, 1983).

2.3. Land concentration and ecological implications

Although 500 000 small producer households populate the Brazilian Amazon (Serrão et al., 1996), land concentration through property aggregation is pronounced in the region. Hoffman (1979) observed worsening land distribution in Amazonia between 1970 and 1975. Darrough (1995) presented data showing extreme instances of concentration in the State of Pará; one current property in the municipio of Altamira comprises nearly 400 000 hectares. Ozorio de Almeida (1992) argued that colonization of the Amazon has failed as a land redistribution mechanism since patterns of concentration throughout the rest of the country have been reproduced in this region. Much emphasis in this regard has been placed on the social dimensions of conflict stemming from the struggle for land (Wood, 1983; Schmink and Wood, 1984, 1992; Berno de Almeida, 1993; Darrough, 1995). Wood (1983) has modified the classical notion of dualism (Fei and Ranis, 1964) and applied it to the agricultural frontier to describe structural relations between large land holders and peasants in the Brazilian Amazon. Wood emphasizes the necessity of these inter-class relations, in contrast to the structural disconnect between redundant rural labor and the industrial expansionism of cities addressed by the early theorists of dualism. An important feature of these relations is land appropriation of small holders, leading to occasionally immense property aggregations (Wood, 1983; Walker and Homma, 1995a,b).

Land appropriations take place forcibly or through market exchanges in competitive land markets; ecological impacts are partly linked to the manner in which they occur. In particular, land dispossession through forced appropriation drives continued frontier expansion—and tropical deforestation—given available land, assuming labor market opportunities remain unattractive (Wood, 1983). On the other hand, land sale at a fair market price could allow the farming household to partake in non-farming investments and activities; such an outcome would presumably reduce the demand for land, particularly frontier parcels with stands of virgin forest.

The market mediations indicated as factors in farm failure, land dispossession, and ongoing deforestation at the frontier are regulated by social structure, the exercise of political power, and changes in the relative supply of land, labor, and capital. In early stages of frontier development, land is abundant and labor and capital are scarce, which establishes and protects the power of small-holders given ready access to land. With frontier settlement, land scarcity arises and a labor market comes into existence as new arrivals encounter difficulty in obtaining land. With continued migration, downward pressure on wages emerges and the relative share of aggregate product appropriated by labor diminishes, leading to immiserization. Powerful landowners, now possessing disproportionate shares of land and capital, are able to apply social power through various instrumentalities in their quest for additional holdings. They can drive down product prices given access to the scale economies of large landholdings or they can diversify directly (or by proxy) into monopolies in the sale of inputs, transportation services, and credit. Market distortions in products, transportation, and credit often impose serious financial burdens on small producers (Ozorio de Almeida, 1992), leading to possible bankruptcy and outmigration to new frontiers (Wood, 1983). In such circumstances, secondary succession occurs given field abandonment; alternatively, sold or appropriated properties may be incorporated into the farming systems of wealthy landowners, thereby promoting land concentration. The land cover impact of appropriation is typically a switch to pasture on the croplands and successional areas of acquired properties since large land holders are often specialized in this activity and additional holdings may improve scale economies.

Despite the focus in the literature on structural phenomena in explanations of land concentration, our Chayanov adaptation suggests a concentration process driven by household evolution. Indeed, small-scale producers can persist in frontier environments under appropriate conditions (e.g., secure title to adequate land holdings; see Wood, 1983; also Ellis, 1993 and Costa, 1995) and succeed in doing so in those parts of the Amazon meeting these conditions (Ozorio de Almeida, 1992). Household decisions involving system switches to pasture necessitate land appropriation given considerations of scale economies; from a regional perspective, this manifests land concentration since households vary in characteristics, evolutionary stage, and readiness to engage in risky investments. Although pasture conversion has often been associated with large-scale corporate farming (e.g., Hecht, 1985), current evidence shows that small operations are viable in the presence of low opportunity costs for labor and capital (Mattos and Uhl, 1994). Small producers, however, maintain high levels of system diversification with generous components of perennials and annual crops (Nair, 1991; Homma et al., 1994). Diversification, as for example from annuals into pasture, can be costly and occurs as families achieve a modicum of economic stability with growth of the household work force and other assets (Walker and Ryan, 1990). As household development continues, crop diversification gives way to more highly specialized systems focused, for example, on particular activities such as ranching. In the CAT idealization, the farming system experiences both quantitative and qualitative changes involving pasture formation, land accumulation, and asset valorization, a felicitous outcome in economic terms. The environmental outcome is conversion to pasture in the wake of settlement and domestic cycles. Evidently, the ecological consequences of land concentration under a Chayanov framework are similar to those arising from capitalist appropriation and class interactions. We surmise, however, on the basis of field observations that capitalist penetration accelerates pasture conversions due to a scale-of-operation effect.

Providing a causal explanation of Brazilian deforestation presents theoretical issues due to the process linkages of small and large producers in farm consolidation and land concentration. Difficulty in identifying behavioral motivations (i.e., productive interest versus speculation) further complicates matters (Ozorio de Almeida and Campari, 1994; see also Hecht, 1985). Frequently, small holders clear land with the express intent of selling it to wealthy farmers attempting to develop large property aggregations. It is problematic to conceptually separate the components of land clearance attributable to the different agents involved if frontier development is viewed as an integrated process involving a succession of producer *types*. Nevertheless, Homma et al. (1994) have stated a dualistic model of environmental impact for the tropical forest biome founded on the microeconomic notion of the production possibilities frontier. Homma et al. (1994) argue that small and large producers face different scale economies, which predispose them to different system choices and, as a consequence, different magnitudes of environmental impact (i.e., deforestation). It should be noted, however, that the household production approach provides that small producers become large producers through time, if domestic cycles and economic conditions lead to asset accumulation.

3. Region–scale context

Domestic cycle phenomena, land concentration, and land cover change are important socio-physical processes contemporaneous with frontier development and regional growth. Nevertheless, regional development theory often refers to social abstractions (e.g., 'urban places') and aggregate variables, as opposed to agent-specific behavior, and pays little explicit attention to physical landscape change. Brown et al. (1994) consider various approaches to region-scale change of landscapes in newly settled areas in Ecuador (see also Browder and Godfrey, 1990; Brown et al., 1992). Landscape evolution is largely driven by the articulation of a system of urban places; such places experience differential rates of growth and development as a function of comparative advantage with respect to resources and location (Muller, 1977). The landscape and city system approaches to development emphasize the early importance of the export of primary goods, both agricultural and mineral. Transportation development serves to integrate production sites and allow further

inter-regional linkages. Maturation of the city system leads to industrial development, the creation of a large regional market, and articulation of central place arrangements determined by scale economies in the provision of services. Presumably, massive conversions of natural areas take place in the wake of such changes.

Urban economics (Fujita, 1989) and derivatives of the Von Thunen spatial model of agricultural land use (e.g., Nerlove and Sadka, 1991) imply a process of natural areas conversion (cf., deforestation) given changes in system parameters and intensification of land use. Land use intensity in Von Thunen-based models is conceptualized in two ways. Nerlove and Sadka (1991) consider the labor-to-land ratio, while Jones and O'Neill (1993a,b) consider rotation times under a traditional technology. Nerlove and Sadka show that at increasing distance from the market node, the labor application per unit land decreases; for traditional technologies, this is consistent with a decreasing rotation period. If the labor-to-land ratio reflects the settlement density, Boserup's empirical observations of the long-run processes of agricultural intensification are reproduced (Boserup, 1965). Increasing population leads to a shortening of fallow times due to land scarcity. Jones and O'Neill (1993a) show explicitly that population growth leads to intensification.

Boserup (1965) criticizes economists' notion of empty land beyond the agricultural fringe. Nevertheless, in formal models allowing for rotational agriculture the fringe may be far removed from the market node. With a gradual de-intensification of traditional technology at increasing distance from the city center, fallow periods can theoretically achieve those consistent with Boserup's long fallow designation, largely consistent with maintenance of the ecological resource base. Reduction of fallows below some threshold must ultimately lead to ecosystem loss with widespread conversion to permanent agricultural lands and degraded ecosystems. Intensity is not only a function of distance and population density, but of prices as well (Jones and O'Neill, 1993a). Nerlove and Sadka (1991) define a point beyond which cultivation ceases due to some minimal labor requirement per unit cultivated land. Extensions of this fringe may be regarded as the initial act of land reclamation that paves the way to eventual encroachment with sufficient intensification of land use (Nerlove, 1994; see also Lambin, 1994). [4] Nerlove and Sadka (1991) also show that increasing population growth expands the agricultural fringe as do reduced transportation costs (Nerlove and Sadka, 1991). Although Hicks-neutral technical change in agricultural production shows no spatial effect, labor-saving innovations could alter the minimum labor necessary to achieve positive production per unit farmland, leading to the expansion of agriculture into natural areas such as forest (Nerlove and Sadka, 1991).

Urban models ostensibly explain transitions from urban to agricultural land, given some positive value of agricultural rent. Nevertheless, nothing intrinsic to these models inhibits their application to direct encroachment into natural areas generating zero rent. In this regard, results identical to the agricultural case obtain with respect to population growth and transportation costs, both of which affect the extensive margin of residential habitation (Wheaton, 1976; Fujita, 1989). Given modern transportation systems and cost, urban markets and agricultural production in the hinterland may be completely decoupled. Walker and Solecki (1995) show that direct urban area encroachment into important U.S. ecological landscapes is a substantial portion of natural areas loss not involving initial conversion to agricultural use. Godfrey (1990) emphasizes the urban nature of contemporary development processes in the Brazilian Amazon. Family structure also has been shown to affect urban space; families with relatively many dependents expand the residential fringe (Beckman, 1973; Fujita, 1989), as does increasing income (Fujita, 1989). Income classes, in turn, show spatial articulation in residential patterns, with wealthier individuals living closer to the town center (Hartwick et al., 1976; Wheaton, 1976; Arnott et al., 1978; Miyao, 1981; Fujita, 1989). The agricultural setting is analogous in that Von Thunen orders space

[4] Bilsborrow (1992) draws a distinction in the deforestation process between land extensification and intensification. Deforestation associated with extensification is essentially the movement of the agricultural frontier into primary forest, while intensification is a filling-in of the agricultural landscape through the removal of remaining forest patches and fallow areas.

into zones of particular crop types on the basis of their rent generation capabilities, with more valuable crops per unit area grown closer to the central market.

The case of the Brazilian Amazon invites a reassessment of conventional land-use modelling frameworks in developing an understanding of the social forces of deforestation in that country. Income classes reflecting similar agricultural agents are critical theoretical constructs in this regard, given the highly skewed distribution of land and income (Berno de Almeida, 1993). An equilibrium pattern of residential (or productive) space shows contiguous land occupation by like-agents whose members enjoy identical utility levels. Rural conflict may stem from falling utility levels attending the increased bid-rents necessary to spatially accommodate burgeoning populations of the rural poor. [5] Ground cover itself reflects the dualistic nature of rural production, and shows patterns at odds with conventional Von Thunen-based prediction. In particular, large landholdings in pasture are often observed closer to urban nodes than small holdings showing more intensive forms of land use (Homma et al., 1994). An income class phenomenon is evidently at work, possibly involving the role of government in protecting property rights, which facilitates access to credit (Schneider, 1995). For this reason, central locations could be preferred by urban-based capitalists able to profit from the scale economies of ranching. Social conflict may also play a role since surveillance costs (for squatting) are presumably much lower close to town, particularly in the absence highways passable during the rainy season. Moreover, subsistence farmers not involved in market production will be largely indifferent to transportation costs, thereby allowing market-sensitive activities priority choice in central place locations. [6]

Current land use theory evidently requires some adaptation for the case of the tropical frontier. Household processes and differential factor mobility are not well-conceptualized in the main theories of land use zonation, which are largely static in nature. The Von Thunen model focuses on the rentability of individual crops presumably taken as products of individual farms. In development frontiers, farms are highly diversified and change their cropping systems with household evolution. In addition, migration patterns and government policy strongly affect the demographic weight of the income classes on location, thereby influencing the balance of political power between them. As a consequence, contingencies stemming from social conflict undermine the prospects for unique land use equilibria. [7] This is to say that the pace of deforestation and the disposition of cleared lands are artifacts of both economic *and* political phenomena, as has been argued by political ecologists (e.g., Blaikie and Brookfield, 1987; Stonich, 1993).

4. Conclusion

In this paper, we have provided theoretical accounts of land use dynamics stemming from endogenous household processes of small producers and from external relations between income (and wealth) classes in the settlement frontier (i.e., social differentiation). We have suggested that land concentration, and related ecological impacts, emerge on the basis of both domestic cycles and the exercise of social power by privileged groups, which we have explained in terms of differential factor mobility. Thus land cover changes and the geography of human settlement in Amazonia result from many factors operating in different social spheres and at different geographic scales (Schmink and Wood, 1992, p. 19).

The relative importance of domestic cycles and social differentiation in explaining observed patterns of land use and ongoing land cover dynamics in the Brazilian Amazon remains a critical empirical ques-

[5] The concept of utility is not as bloodless as many micro-economics textbooks would suggest. Nakajima (1969) states indifference curves with survival flats for the trade-off between a subsistence farmer's income and leisure. Presumably, the family starves when income falls below the income level indicated; it goes within saying the family would be willing to trade an infinite amount of leisure for an additional unit of income when economic circumstances have reached this point.

[6] We credit David Greenstreet with this observation.

[7] A number of development externalities also affect land use patterns in the Brazilian Amazon. High-value-per-unit-weight products are particularly susceptible to theft, and susceptibility is largely a function of distance from major urban areas.

tion. We argue that both phenomena are present. Sizeable aggregated properties with resident owners are common in older settlement frontiers, such as the Transamazon Highway; such properties probably represent the successful outcome of household accumulation. On the other hand, very large and undeveloped properties are recorded throughout the region; these have presumably been appropriated. Political violence linked to the land issue has been intense in parts of the Brazilian Amazon, particularly in the States of Pará and Maranhão (Berno de Almeida, 1993; Darrough, 1995), which is consistent with a process of appropriation.

In the Brazilian Amazon, it is impossible to separate the ecological problem of deforestation from the social issues of land concentration, rural violence, and frontier development. For this reason, it is also impossible to consider ecological sustainability apart from social sustainability; sustainable relations with the environment necessarily involve positive relations between individuals and social groups. Such relations can be promoted by policies aimed at the plight of the rural poor involving, for example, more aggressive extension activity and the development of public infrastructure. Unfortunately, social harmony is more difficult to achieve and probably more expensive than the design of a sustainable farming system. It is not our intention to suggest a solution to this impasse. Rather, we seek to emphasize the systemic nature of the issues involved, and to strongly resist temptations to view sustainability of the Brazilian Amazon as an environmental problem requiring only a technical solution.

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