LAND COVER EVOLUTION OF SMALL FARMS: THE TRANSAMAZON HIGHWAY

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ABSTRACT- The dynamics of land use change in both the mid and long-run were determined for a sample of 132 small farmers located along the Transamazon Highway. On average, four deforestation events occurred after arrival on the property. The average area of deforested land was 10 hectares for each event, totaling 40 of the 50 hectares allowed by law for a typical size plot of 100 hectares. It was observed that small farmers along the Transamazon Highway employ diversified systems of land use including annual crops, perennials and cattle; these show a temporal sequence in accord with household domestic cycles. These results suggest that pasture conversion in Amazon by small farmers is due to domestic dynamics cycle in addition to others variables.

Index terms: Land use, Transamazon, deforestation, domestic cycle, Amazonia

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A EVOLUÇÃO DA COBERTURA DO SOLO NAS ÁREAS DE PEQUENOS PRODUTORES NA TRANSAMAZÔNICA

RESUMO- A dinâmica da mudança da cobertura vegetal a médio e a longo prazos foi determinada para uma amostra de 132 propriedades na Transamazônica. De acordo com os dados levantados, verificou-se que ocorreram, em média, quatro desmatamentos durante oito anos após o seu estabelecimento na propriedade. A média de área desmatada foi de 10 ha em cada etapa, totalizando 40 ha de um limite estabelecido legalmente de 50 ha, considerando um lote típico de 100 ha. Foi observado que os pequenos produtores, ao longo da rodovia Transamazônica, possuem sistema diversificado de uso da terra envolvendo culturas anuais, perenes e pecuária, que sofrem evolução de acordo com o ciclo doméstico. Estes resultados sugerem que uma parte da conversão de pastagem na Amazônia é devido à dinâmica do ciclo doméstico, associado a outras influências.

Termos para indexação: Uso de terra, Transamazônica, desmatamento, ciclo de vida, Amazônia

INTRODUCTION

Land use decisions are influenced by a variety of endogenous and exogenous factors to the farm. Market conditions and soil resource base evolve through time, providing a dynamic set of system choices to the farmers. Simultaneously, the farmer acquires human capital and labor resources as children grow up and are integrated into the production process. With the aging of the household group, these productive resources may decrease, leaving the farmer with serious production constraints. Alternatively, adult children who have managed to find profitable off-farm employment, perhaps in a city, may choose to finance the ongoing development of family farming activities.

The land use system in place at any point in time and its articulation as a form of land cover are the result of many factors interacting in an evolutionary

process. These processes have been described for land-abundant tropical frontiers in CAT (1992) and Homma et al. (1993). These authors indicate that farm creation is a long-term process in which land is claimed from virgin forest for production purposes. CAT (1992) suggests that the typical outcome for such a process is conversion to pasture. Homma et al. (1993) developed a deforestation concept which links crop choice and family resource base to the rate and the extent of deforestation (Homma et al. 1993, p. 6).

This paper integrates conceptually the approaches of CAT (1992) and Homma et al. (1993) and builds a land cover change model based on the current situation along the Transamazon Highway. Discussions of deforestation often take place at an aggregate level and are rarely presented in terms of agricultural production processes, leading to increasing demand for productive land, the primary driving force of deforestation. By way of contrast, we present the actual transformations which have occurred in this regard in the region, and we implement our model with empirical data gathered from a survey of 132 small farms located in the Transamazon Highway, in Pará State.

MATERIALS AND METHODS

One type of current economic researches on Amazonian farming considers the profitability of individual establishments. These kinds of researches have been based on the traditional cost-benefit analysis and relied on a complete characterization of the costs and the revenues for an idealized farm or ranch, a shifting-cultivation operation, or a perennials plantation. Financial analysis leads to an appraisal of profitability, in terms of internal rate of return to some initial investment. One purpose of such analysis is to identify profitable land-conserving systems; another is to assess the profitability conditions of land-extensive systems such as cattle ranching. (See for example Toniolo and Uhl 1994; Mattos and Uhl 1994; Trindade de Almeida and Uhl 1994; Hecht 1992; Hecht, Norgaard, and Possio 1988).

Some of the cost-benefit applications to resource-conserving systems seem to suggest that imperfect information inhibits their adoption, and that analytical explication of costs and benefits is important to promoting the implementation of such systems. This is an empirical question. Certainly, information on

potential farming system performance is incomplete under any set of circumstances, given uncertainty in price movements, etc. Our interest resides in observed performance; we argue that the empirical setting, involving conditions such as price variability, is of critical importance in assessing the appeal of farming systems to potential adopters. Actual farms which have survived necessarily meet some criteria of economic performance (e.g. profitability) in addition to meeting behavioral necessities of the farmers themselves.

Although these normative idealizations involve detailed information on conditions on the ground in Brazil, they do not reveal the ongoing process of change and adaptation that characterizes many farms; nor do they indicate the extent of land clearance likely to be associated with any given set of household characteristics. Farming system evolution is clearly linked to prices in labor and product markets, but internal conditions in the household, as well as attitudes toward risk, also play a role. We posit a dynamic household production model (Sing, Squire, and Strauss 1986) in which the household resource base evolves along with the goals of household members (Watkins, Leinbach, and Falconer 1993). We hypothesize that as the internal balance of labor power and consumption changes, so does the disposition toward risk-bearing, leading to alterations in crop selections and consequently dynamic land allocation. Proletarianization stemming from the colono system (see Rudel 1993, pp. 18-22) and distortions in rural product and credit markets (Ozório de Almeida 1992) affect the land use decisions of small producers. Our focus, however, is mainly on the role of internal domestic structure. Thus, our model addresses the link between production system and household structure, and not the relationship between agricultural adoption, input prices, outputs, and capital. We recognize the importance of the external economy, but in this paper we draw attention to the role of the internal household economy in crop selection.

Recent research carried out in the neighboring area provided a detailed description of dynamic household forest interactions germane to the present discussion (CAT 1992). 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 resources 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 a stock of secondary forest.

As children grow up, the labor supply is increased, and new ventures can be undertaken. At this stage, the family may accumulate sufficient capital to buy more land; if successful, land is cleared for pasture and several head of cattle are purchased. With continuing additions to the family workforce, and eventual participation in the local labor markets by family members, the household is able to further augment investments in cattle. As presented in its original form, the cycle ends with land valorization, and the accumulation of family wealth. Associated with this felicitous outcome is an ongoing dynamic between land use and the resident ecosystem. In particular, 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).[1] *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.*

A development cycle process may be conceptualized in general using the model advanced by Turner, Meyer, and Skole (1994) linking driving forces of land cover change via so-called proximate "sources" arising from particular land use decisions. We desegregate the driving forces of land cover change into the agent involved (i.e., the small producer household) and external economic factors (market conditions, etc.). As the household structure changes with time, land use also changes, leading to evolving forms of land cover. The land cover itself may ultimately affect the household's economic status by restricting crop choices through environmental degradation. For example, land use for annuals 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, such as ranching, may be implemented. Ranching, in turn, leads to new forms of

herbaceous land cover, which 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 crops with low nutrient demands like cassava.

Unpublished results by Walker (1994) are consistent with this conceptual model. In particular, bivariate correlation is positive between the age of household head and the percentage of labor time allocated to investment crops (perennial production plus ranching activities). If the time allocation variable used in the correlation is interpreted as a measure of intensity of involvement in investment crops, then the positive relationship fulfills the expectation of the domestic cycle hypothesis. That is, advanced stages of the domestic cycle (indicated by age of household head) are associated with increased involvement in investment crops production. Walker also showed bivariate relationships between farming system type (as measured by labor time allocation) and extent of land cover transformation at the farm level. The labor time allocation to ranching is positively correlated with extent of deforestation, while allocation to annual crops production is negatively correlated. Allocation to perennial production shows no correlation with the degree of deforestation, suggesting a land cover impact between that associated with ranching on the one hand, and annual crops production on the other.

Mid to long-run land cover change dynamics were determined for the 132 sample properties in the analysis presented here. This was accomplished by analyzing questionnaire responses regarding the relationship between natural cover (forest and secondary growth, or capoeira) and cropping. Transition probabilities were calculated for the change from virgin forest and secondary growth into pasture and perennials; the residual probability is abandonment to cyclic agriculture. The probabilities were then applied to a sample farm to check for consistency with pasture creation. Our expectation, given domestic cycle theory, is that farms in the sample will show continuous development into pasture and perennials, given the average residence time of 14 years and concomitant changes in the household resource base. Such evolution is consistent with reduction in risk aversion, since the new systems require investments in uncertain outcomes. In the discussion that follows, deforestation is taken to be the conversion of virgin forest, or old-growth stands largely indistinguishable from primary growth. While the removal of older secondary growth (e.g.,

capoeira) technically involves the removal of large trees, which is a type of deforestation strictly speaking, we will refer to such land preparations as clearance.

RESULTS AND DISCUSSION

Deforestation occurs as a result of the process of land occupation in the early years of farm establishment. Institutional incentives promote land clearance, but the primary motive stems from the demand for land (Ozório de Almeida 1992). The capability to clear land is based on the family workforce and it is enhanced by the possession of equipment (e.g., a chainsaw). Although the average length of residence on properties in the study area is approximately 14 years, which means that upon arrival families were fairly young given the current average age of heads of household (52), the mean initial workforce was about 4 at the start of operations, sufficient for forest clearance and parallel agricultural activities (see CAT 1992 on clearance costs and productivity). Deforestation may continue throughout the life of the farm operation, but deforestation acts are clustered in the initial years. Presumably, such timing helps affirm claims to land and also allows for the creation of an excess stock of secondary forest. An excess stock provides (1) a clearance hedge that enhances land value; (2) sufficient quantities of easy-to-clear regrowth, necessary for the maintenance of rotational agriculture in the face of uncertain family size; and (3) cost-minimization over the long-run in land clearance.[2]

The sample of small producers indicates on average four deforestation acts occurring over an eight-year period immediately after farm establishment. These individual acts involve on average about 10 hectares of land, leading to a total deforestation level on the order of 40 hectares, which is within the 50 hectares limit of land clearance set by law for 100 hectare properties. It should be noted that owners may have arrived on the farm after substantial deforestation had already occurred, in which case an additional 40 hectares of land clearance could substantially exceed the legal amount. The small producers on the Transamazon Highway employ highly diversified land use patterns, with elements of annual crop production, perennials, and cattle. Thus, the land cover categories observable are forest, capoeira, perennials, pasture, and annuals. Perennials and pasture represent fairly stable land cover outcomes, at least over the short-run; for the purposes of this presentation,

this will be assumed to be the case.[3] *Transitions between these various land cover types are observable from the survey data. In particular, dense forest is converted to perennial production 26 percent of the time, and to pasture 43 percent of the time; the residual (31 percent) is abandoned to cyclic agriculture. Clearance of capoeira to pasture is aproximate to the figure for virgin forest, 46 percent. Perennials conversion is much lower, however (12 percent), and 41 percent of capoeira fields are rotated (Figure 1).*

When capoeira or dense forest is cleared, a year or two of annual production follows, immediately prior to conversion to pasture or perennials, or to abandonment to capoeira. Land cleared from capoeira can itself be abandoned to capoeira after annual cropping, under rotational management; the average age of capoeira used in rotation is between four and five years, which can be interpreted as the average period for the burn cycle in the region.

This data reveals important aspects of the evolutionary processes of farming in the region. In particular, strong impulses to permanent conversion exist, both from dense forest directly, and through capoeira. Around 69 percent of the dense forest conversions are permanent, while nearly 58 percent of capoeira clearance leads to the same outcome. Although the dominant tendency is toward pasture creation, as is indicated in CAT (1992), a substantial quantity of land ends up in perennials production. Moreover, rotational agriculture apparently remains active, since a considerable amount of capoeira is recycled upon clearance (41 percent). It is important to place several qualifiers on these results. First, the percentages are not for actual area units, but for typical fields, as defined by individual respondents.[4] *Second, perennials may also be converted to pasture, although we have not calculated this pathway of change. We presume it to be small but non-trivial, in which case eventual conversion to pasture may represent the long-run outcome in the absence of additional dense forest to clear. Nevertheless, for the time periods involved in our sample, perennial land cover is a relatively permanent landscape feature.*

The empirical findings on deforestation and land cover groupings can be combined to produce a portrait of farming system evolution along the Transamazon Highway. In particular, if ten hectares of dense forest are cut every other year starting upon arrival, then 40 hectares have been cleared by year 7, and 17.2 hectares of pasture have been produced directly from forest

*(40 hectares * .43). Starting with year 5, capoeira begins its cycle. If it is assumed that plot utilization is for two years, following the staggered forest clearance timing, and if pasture is created from capoeira every time it is rotated, then the 3.1 hectares of capoeira created with each deforestation event will yield a series of pastures, converted at 46 percent of the current capoeira stock. Allowing for perennials conversion, this yields four deforestation series, leading to 27 hectares in total pasture by year 14. This quantity is consistent with the average of 35 hectares of pasture conversion calculated from the data. The both calculations suggest that the stock of capoeira rises at first, and then is depleted following the last of the deforestation events.*

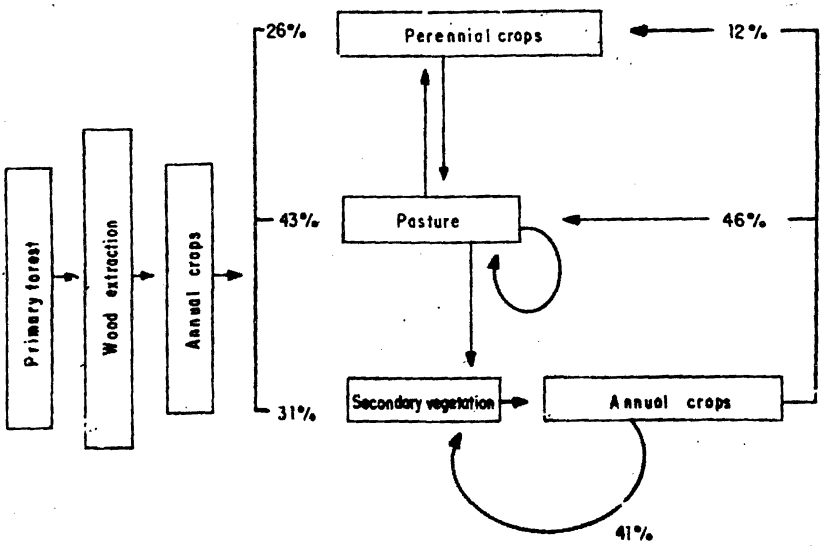

Figure 1- The dynamics of land use by small farmers along the Transamazon Highway.

CONCLUSIONS

This paper presents an argument and evidence on dynamic household processes, based on observed patterns of land use and land cover change. Although a rotational component is maintained in the typical farming system, the overall tendency is of conversion to pasture and/or perennials; these results are consistent with the elaborated theoretical framework. Thus, farming systems appear to diversify to components requiring investments of time, labor, and capital, as suggested by the domestic cycle model. The apparent magnitude of the discrepancy between 27 and 35 hectares is likely accounted for by restrictive assumptions used in the calculations. In particular, the average pasture conversion is probably larger than perennials or annuals conversion; nevertheless, an identical field size was used for computational ease. Moreover, some perennials are ultimately converted to pasture, once the productive life of the vegetation has expired. Failure to redress either of these issues in the computational approach lowers the final pasture value determined.

Our results suggest that some component of pasture conversion in the Brazilian Amazon region is attributable to domestic cycle processes, in addition to other likely influences. Ascertaining the relative size of this contribution represents an important area for future research, and is of key importance to policy-makers.

ENDNOTES

1- 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.

2- Eventually secondary forest will be cleared for pasture and perennials. Although much of total costs are absorbed by labor time, chainsaw rentals are probably fixed.

3- Of all properties with current pasture, only 12.5 percent have abandoned some pasture in the past. The average size of abandonment is 1.53 hectares, much smaller than the average amount of pasture formation since the beginning, about 35 hectares.

4- These change percentages were calculated on the basis of a question to each producer asking what kind of vegetation he or she was accustomed to using, and what crops were typically planted following vegetative clearance. Thus, this data does not necessarily represent the actual frequencies of change presently occurring in the region; rather, they indicate conversions that would presumably take place under normal practices, as described by the respondents. We did not acquire information for individual fields on the various properties.

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