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The urban-rural interface: Urbanization and tropical forest cover change

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Abstract. A considerable body of empirical and theoretical literature on the causes of tropical deforestation has emerged over the last twenty years. Recognizing that small-farmers in the Amazon Basin are a key agent in the process of primary forest conversion, a growing genre of studies at the household level have attempted to quantify the influence of various factors on small-farmer land-use decisions. Many of these studies have acknowledged the seeming importance of urban centers as hubs of propulsive activity and information, yet none have comprehensively captured the "urbanization factor" in rural land use decisions. I argue that this methodological shortcoming in empirical work to-date reflects an inadequate conceptualization of the range of urban-based networks and their inter-relationships. In an effort to overcome this roadblock to further empirical discovery, I review several leading schools of thought that might be pressed into service in developing a framework for interpreting the urban influences on rural landscapes. I call this construct the "Urban-Rural Interface." This is not a complete theoretical model or a unique methodology, but rather an initial effort to develop a general framework from which more sophisticated formulations might proceed.

Keywords: urban-rural interface, Amazonia, tropical deforestation, urbanization, social networks

Introduction

The research literature on the causes of tropical deforestation has grown so rapidly over the last 20 years that it has itself become the subject of critical research (LEEC, 1992; Kummer and Sham, n.d).[1] Much of this social science research has focused on macro-level "drivers" of land cover change (e.g., population growth, public policies, structural adjustment, monetary policies, etc.). In contrast, a small, but growing number of micro-level studies have focused on rural producers (small farmers and ranchers) as the primary agents of land cover change. Of course, the great challenge ahead is to merge research at these two vastly scale-disparate levels of analysis. Getting there requires finding some missing pieces to the puzzle. An entire stream of missing pieces to this curvilinear jigsaw of causality, pertain to the role of urban centers in rural landscape change. And that takes us back to rural producers, in whose hands the fate of much of the Amazon Basin resides.

For the most part, these rural producers have been widely conceptualized as relatively autonomous economic agents basing their land use decisions on production factors internal to the household and in rational response to exogenous market prices for the commodities they produce. However, rural producers are embedded in larger social and spatial contexts and participate in various economic, social, economic and political networks, and their land

use decisions are often not so easily derived from economic rationality alone. Our recent research (Browder and Godfrey, 1997) suggests that the urbanization of the Amazon during the last 30 years has profoundly changed the social and economic contexts defining how rural producers use land. Our study found significant differences in land use patterns between urban-based farm owners and rural-based farmers. And, we found that increasing numbers of rural properties are ending up in urban resident ownership, suggesting that rural property ownership and land use are becoming part of complex urban-based household strategies.

Recognition of the importance of urban-rural linkages is not new. In 1970, E.A.J. Johnson, in his benchmark work noted that "it is incorrect to assume that urban entrepreneurial decisions are wholly discrete and separable from rural decisions and choices" (Johnson, 1970:183). Could it also be said that important rural entrepreneurial decisions (i.e. land use decisions) are related to the urban influences in some significant ways? Despite the apparent importance of the urban-rural relationship in explaining tropical forest cover change, very little has been written about the subject either conceptually or empirically. In this paper, I propose a modest schematic framework for conceptualizing the seemingly daunting challenges of integrating complex urbanization factors into rural landscape change outcomes as determined by rural landowners.

This paper briefly reviews a sample of empirical (household level) studies that seek to explain rural land use change in Amazônia to illustrate, in part, the difficulty that researchers have had in conceptualizing the relationship between urbanization and rural land use. In the second section several conceptual frameworks that might contribute to a new understanding of urban-rural linkages are considered. Finally, I outline a hybrid theoretical construct, which I call the "urban-rural interface", that might provide a general framework for more specific models that could be used in future empirical work interrogating the relationship between urbanization and tropical forest cover change.

Recent empirical studies of rural land use change in Amazonia

Although urbanization of the Brazilian Amazon frontier has proceeded at a breath-taking pace since 1980, very few of the recent studies on land cover change in the region have explicitly taken into account the influence of urbanization on rural land use. This is so, I believe, because those "urban factors" have not been adequately conceptualized. Several excellent studies have been published recently that seek to explain rural land use change in Amazonia. This emergent research literature has been largely framed by three different theoretical traditions: neoclassical economics (Scatena *et al.*, 1996; Vosti *et al.*, 1998; Caviglia and Kahn, 2001), demography and human ecology (McCracken *et al.*, 1999; Perz, 2000; Moran *et al.*, 2001; Pan *et al.*, 2001), and political ecology (Collins, 1986; Ozorio de Almeida, 1992; Stonich, 1993). Other scholars have adopted hybrid conceptual frameworks for interpreting why farmers deforest and shift land uses over time (Fearnside, 1985; Pinchón, 1996, 1997; Angelsen and Kaimowitz, 1999). A diverse compendium of recent international case studies exploring various issues associated with the urban-rural divide are found in Tacoli (1998).

The neoclassical economic literature tends to privilege the utility maximization assumption about farmer land use behavior. The results of economic studies tend to support two

conclusions concerning land use change in the tropics: First, empirical land use research has successfully identified several diverse drivers of landscape change, including: agricultural prices (for both inputs and outputs) and more broadly commodity markets; credit use (especially the use of government subsidized, crop-targeted credit program); natural resource endowments and rent capture (e.g., timber sales); and accessibility (distance to market and input suppliers). Macroeconomic factors such as national income and economic liberalization also appear as underlying drivers of landscape change. Second, our understanding is much clearer of the factors influencing deforestation than of those influencing subsequent land use. While many of the variables seen by economists as determining land use are directly and indirectly linked to urbanization, economists working from a neoclassical economics perspective have yet to formulate an analytical model that accurately represents the structure of urbanization forces and the relative influences of specific urban factors on the rural landscape change.

The demographic and human ecological research on tropical forest landscape change emanates from the tradition of Chayanov (Thorner *et al.*, 1986). Such research seeks to explain land use change in the Amazon based on household level demographic variables set within a "domestic life cycle" framework. Three general conclusions emerge from this research literature. First, while most of the models tested include three different types of independent variables (demographic, farm site characteristics, and socioeconomic/institutional), the low correlation and regression coefficients resulting from these studies suggest that other unspecified non-demographic factors play a large role in explaining the variation in observed land uses, a fact that many demographers acknowledge. Second, the models tend to focus on the household scale, in which the farm family unit and associated plot is the basic unit of analysis. Economic and institutional factors exogenous to the household emanating from regional, national, and global scales (e.g., commodity prices, interests rates, tax policies, and urbanization effects) virtually escape treatment in most of these demographic studies. Third, the very nature of the prevailing demographic framework, the "household lifecycle," implicitly lends itself to a linear, evolutionary, stages approach to conceptualizing the dynamic relationships between land owners and land use. While this approach may provide a useful overarching background, the studies to date do not address decisive perturbations in this linear transitional process that might arise expectedly from exogenous forces. Undoubtedly, some of the unexplained variation in these studies arises from the difficulty in conceptualizing and measuring these "non-linear" influences on household land use decision-making, such as those that might be associated with urbanization.

Finally, political ecology approaches to landscape change in Amazonia have drawn largely from neo-Marxist interpretations of the global division of labor, unequal exchange and surplus extraction. Most political ecology approaches situate the local dynamics of land use change in the larger context of the global expansion of capitalism (e.g., Blaikie, 1985). In the Brazilian frontier context, for example, landless farmers are pushed into the Amazon, applying their labor value to the land by clearing forest and planting short-term subsistence crops. This initial stage of frontier settlement paves the way for subsequent "penetration/incorporation" by agribusiness and other social elites who appropriate the labor value "congealed" in the landscape, and push the peasantry off the land once again in a perpetual cycle forest destruction and social expulsion and itinerancy. Landscape change

Table 1. Summary of selected land use studies in Amazonia

	1*	2*	3*	4*	5**
Dependent variable:					
Land use (all types)*					
Sustainable land use**					
Independent variables:					
Soil quality	+	+	+		
Farm size	+		+		
Adult farm labor	+	0	+	+	
Household education	+	+	0		0
Farming background	0			+	
Land tenure security	+	+	+	+	
Distance from market	–	–	–	–	
Duration of farm	0	0	+	+	+
Off-farm income	–	–	–	–	
Urban link		0			
Forest product extraction		–			
On-farm wage labor		+	+	+/–	
Social participation				+/–	+
Initial capital (wealth)			+	–	
Use of credit				+	
Technical knowledge	0				+
N	419	150	762	261	196
R^2	..30–.52	n.a.	.21–.6	.25–.44	.34

Note: "+" denotes increase in area in production (all land use types), "–" denotes decrease in area in production, "0" signifies no statistically significant impact on land use.
*Land use of all types, $p < .10$.
**Sustainable land use, $p < .10$.
1. Pinchon, 1997a
2. Vosti *et al.*, 1998
3. Pan *et al.*, 2001
4. Perz, 2000
5. Caviglia and Kahn, 2001

is a predictable outcome of this inexorable process of capitalist expansion. With the exception of a small number of structuralist geographers, not expressly political ecologists (e.g., Armstrong and McGee, 1985; Torres, 1988; Becker, 1985), the urbanization question has alluded critical analysis in the political ecology literature. As much can be said for the studies arising from the demographic and economic traditions as well (Table 1). In only one of these studies (Vosti *et al.*, 1998) is urbanization explicitly considered, and, given how narrowly the urban factor is defined in this study (using a distance surrogate), its influence on rural land use was found not to be statistically significant.

It would appear that the disjuncture between scholars engaged in rural land use change research, on the one hand, and urbanization, on the other, emanates from the shared assumption that these are intrinsically distinctive and unrelated processes. Yet a fuller understanding of the dynamics of both processes will likely necessitate some conceptual "bridge-building" between them.

Given the contemporary urgency of the tropical deforestation problem and the rapid urbanization occurring in tandem in most tropical countries, it is perhaps surprising that so little has been written on urban-rural linkages of late. For the most part, the existing literature is framed by gravity-type models, in which urban population size and distance factors determine land use. Accepting the general validity of that approach, however, does not preclude systematic consideration of other approaches to conceptualizing what I call the "Urban-Rural Interface" (URI): That tapestry of multiple, interacting networks linking urban and rural areas that mediate the processes of rural landscape change. To initiate this discussion it is useful to briefly consider the contributions of several conceptual frameworks.

Theories of urbanization and rural land cover change

Recent interest in the impacts of urbanization on rural landscapes has largely focused on urban sprawl and farmland conversion (Furuseth and Pierce, 1982; Walker, 2001), agricultural intensification (Rondinelli, 1986; Bhadra *et al.*, 1993), and rural settlement patterns (Bunce, 1982). These interests provide a foundation for empirical research of rural land cover change in developing regions and are informed by several leading theories. Among the most influential of these conceptual frameworks is the work of Johan Heinrich von Thunen (Hall, 1966).

Thunian models and market rationality

Contemporary economic theories of regional development tend to view landscape or environmental change as a function of the growth of towns and cities in a regional settlement system and have spawned a genre of probabilistic models and deterministic theories of land use change based on principles of market rationality. Starting from Von Thunen's classic "concentric zones" model, landscape change is seen as a response to changes in economic land rents associated with increasing transportation costs from a central market place (Bryant *et al.*, 1982). Von Thunen's contribution to the geographical interpretation of landscape change has been considerable and warrants more detailed review than I give it here. Katzman (1977) adapted a Thunian approach to Brazilian agricultural land use that illustrates the general principles of this approach (figure 1).

Three zones of commercial cultivation occur. In the zone immediately surrounding the market center a "greenbelt of perishables" appears consisting of truck farms producing low-value, high yield vegetables for local market consumption. The second zone is dedicated to the medium-value cash crop coffee. In the frontier zone, high-value, low-yield cattle, rice, or soy bean crops are produced. Beyond the commercial frontier lies a zone of diversified subsistence farming (p. 222).

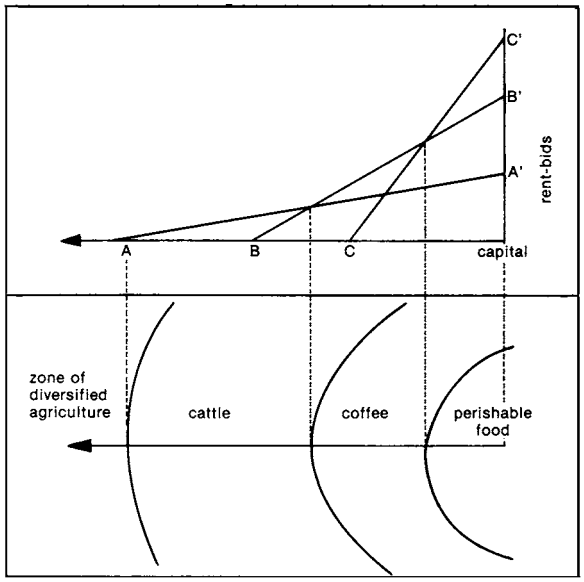

Figure 1. Rent-bid curves for cattle (AA′), coffee (BB′), and perishables (CC′) and zones of specialized production derived from rent-bid curves. *Source:* Martin T. Katzman (1977) Cities and Frontiers in Brazil. Harvard University Press, Cambridge, p. 223.

Katzman considers the food demand effects of increasing urbanization on the Thunian land use rings. As urbanization increases the gradient for perishables is pushed outward, forcing a contraction in the area devoted to coffee production. Growth in the demand for beef or rice would push the outer limit of coffee production inward. If the contraction of coffee production is of sufficient magnitude to cause world prices to rise, then the result of growth in demand is the expansion of all cultivation zones. Katzman notes that this idealized urbanization effect on prices and supply did not occur in Brazil because crop prices have not increased. According to Katzman, the major factor driving the expansion of the commercial agricultural frontier has been marketing infrastructure improvements (e.g., expansion of the highway network) and a consequent flattening of the rent-bid gradients leading to a reduction in market risk and consequent specialization. More broadly, the expansion of the agricultural frontier in Amazonia has been driven by public policy, especially the provision of various subsidized credit programs, as well as direct expenditures for infrastructure and settlement (Browder, 1988).

Von Thunen was well aware that certain conditions might distort a regular concentric ring pattern of land use around the city. Variations in physical resources (e.g., non-uniform soil quality), alternative transport routes, the emergence of competing centers would likely instigate aberrations in the land use gradients.

From the Thunian perspective, the rural area (the "hinterland") is assumed to be a smooth, socially undifferentiated space, two-dimensional surface. From recent research we know that the social composition of space is a critical factor influencing land use. Our own work on urbanization in Amazonia supports the view that the region is a heterogeneous,

"disarticulated" social space. "The confluence of different social groups originating from processes occurring at different socio-spatial levels of the global economy during overlapping historical periods renders the Amazonian landscape a 'mosaic within mosaics,' something that is incomprehensible through the optic of any single conceptual lens or master principle" (Browder and Godfrey, 1997:362).

One might say that *a priori* the Thunian framework is of limited applicability to the question at hand of conceptualizing the relationship between urbanization and deforestation since the latter typically occurs beyond the outer limit of commercial agriculture in the vast undifferentiated zone Katzman refers to as "diversified agriculture". Whether the Thunian model could be extended to accurately identify additional zones of rural land use beyond the periphery remains an open question.

Growth pole models

Another group of studies of urban-rural linkages, or core-periphery dynamics, has drawn from the "Growth Pole" concept of Francois Perroux (1950), such as Nichols (1969), Parr (1973) and Hansen (1975), among others. Although intended to provide a framework for understanding the process of structural economic change in an urban system, and not the affects of urban centers on rural land use, growth pole theory gave credence to the notion of economic space as a "field of forces" and hence to the possibility of urban-based economic networks as "drivers" of structural change (including rural landscape change) in the periphery. A major analytical challenge presented by growth pole economics is how to measure the hypothesized "spillover" effects of investment in the "propulsive" manufacturing sectors of the urban center upon its rural (economic) hinterland. This question continues to be of interest to regional geographers. While several studies have attempted to evaluate the "spread" and "backwash" effects of urban growth upon its periphery using intra-regional input-output models, the findings of this research remain empirically inconclusive with vague implications for rural land use (e.g., Hughes and Holland, 1994; Barkley *et al.*, 1996). Nonetheless, the notion that intra-regional economic development in the core (urban nodes) produces a complex set of dynamic spatial processes in its periphery (rural hinterland) constitutes a major legacy of growth pole research.

Innovation diffusion models

Interest in the propagation and diffusion of innovations as a spatial process also might enrich the analysis of urban influences on tropical deforestation (Hagerstrand, 1952, and subsequent applied studies, e.g., Shannon, 1970; Johansen, 1971; Misra, 1969; Bowden, 1965; Brown, 1981, arguably provides the most complete review). Hagerstrand conceptualized diffusion as the outcome of a learning process within a network of social communications, given the presence of barriers which impede communications. Brown (1981:19–22) describes three developments ("strands of coalescence") in diffusion research two of which have implications for landscape evolution. One development is found in the works of Pred (1973) and Robson (1973) on urban systems evolution. These works tend to emphasize the importance of population and distance in explaining patterns of diffusion of technical

innovations, and may be regarded as derivative of the Thunian framework. By contrast, Brown and Malecki (1977) suggest that decisions leading to diffusion that affect landscape evolution have an organizational context that defies explanation by simple gravity models. A second development focuses on the mediation of diffusion through "activity systems" (systems of social, economic and personal resources characterizing the milieu of potential adopters) (Carlstein, 1978). Both developments, supported by various applied empirical studies, broaden the range of variables that might be considered pertinent to the question of urban influences on rural landscapes.

Regional planning flow models

Other researchers have focused on urban functions in promoting rural development and the types of linkages and flows between urban and rural places. For example, Rondinelli and Ruddle (1978) developed a framework and methodology for what they called "integrated spatial development planning" noting that "a complex set of linkages transforms and integrates urban and rural areas in developing nations" (p. 161) (Table 2).

> A complex set of linkages transforms and integrates urban and rural areas in developing nations. Physical, economic, technological, and social linkages and population movement, service delivery, and political, administrative, and organizational patterns play potentially important roles in the transformation of poorly articulated spatial systems" (Rondinelli and Ruddle, 1978:161).

Gaile (1980) also outlined some of those urban-rural linkage processes as intra-regional flows induced by metropolitan area growth (Table 3).

Social capital theory

Recent interest in "social capital" (see Dasgupta and Serageldin, 2000; Lin *et al.*, 2001) expands the field of conceptual possibilities for exploring rural-urban linkages in landscape change. James Coleman is credited with having coined the term "social capital," defining it broadly as "social structures that facilitate certain actions of actors within the structure" (Coleman, 1988:S.98). Robert Putnam refers to social capital as "a set of horizontal associations among people who have an effect on the productivity of the community" (Putnam 1993 cited in Serageldin and Groutaaert, 2000:45). Nan Lin considers social capital to be "resources embedded in a social structure which are accessed and/or mobilized in purposive actions" (Lin *et al.*, 2001:12). Social capital is not just an input into a production function like physical capital (produced assets) and natural capital, but rather, like technology, it becomes a "shift factor" (or exponent) of production. Recent research by the World Bank (1997) indicates that human and social capital equals or exceeds natural capital and produced assets (constituting 60% of total wealth) in 192 countries. Although an emergent and growing literature (e.g., Narayan and Pritchett, 2000; Robalino, 2000), research on the role of social capital networks in mediating urbanization impacts on surrounding landscapes has

Table 2. Major linkages in spatial development

Type	Elements
Physical linkages	Road Networks
	River and water transport networks
	Railroad networks
	Ecological interdependences
Economic linkages	Market patterns
	Raw materials and intermediate goods flows
	Capital flows
	Production linkages—backward, forward, and lateral
	Consumption and shopping patterns
	Income flows
	Sectoral and interregional commodity flows
	"Cross linkages"
Population movement linkages	Migration—temporary and permanent
	Journey to work
Technological linkages	Technology interdependences
	Irrigation systems
	Telecommunications systems
Social interaction linkages	Visiting patterns
	Kinship patterns
	Rites, rituals, and religious activities
	Social group interaction
Service delivery linkages	Energy flows and networks
	Credit and financial networks
	Education, training, and extension linkages
	Health service delivery systems
	Professional, commercial, and technical service patterns
	Transport service systems
Political, administrative, and organizational linkages	Structural relationships
	Government budgetary flows
	Authority-approval-supervision patterns
	Interjurisdictional transaction patterns
	Informal political decision chains

Source: Rondinelli and Ruddle (1978:162).

Table 3. Intra-regional flows stimulated by growth of the metropolitan core area

Flows of investment funds
Urban funds are invested in rural areas to take advantage of relatively low labor and land costs (spread)
Rural funds are invested in urban areas to take advantage of relatively rapidly growing goods and services markets (backwash)
Flows of spending for goods and services
Urban growth provides expanding markets for rural producers (spread)
Spending in rural trade and service markets declines due to increased competition from the more varied and efficient urban producers (backwash)
Flows of people
Rural labor commutes to the urban area for employment (spread)
Urban families relocate residences to rural areas because of lower real estate costs and perceived higher quality of life (spread)
Rural residences migrate to the urban areas for better access to employment and urban lifestyle (backwash)
Flows of firms/employment
Firms in the mature or declining stage of product life cycle locate in rural areas to take advantage of low wages and land costs (spread)
Firms in the innovative or growing stage of product life cycle locate in urban areas to benefit from agglomeration economies, markets, and specialized labor (backwash)
Flows of knowledge and technology
Urban centers are the generators and diffusers of information and innovation for rural areas (spread)
Social attitudes in rural areas are transformed by the "demonstration effects" of high wages and expanding markets in the urban core (spread)
Rural to urban migration is selective of the better educated and more highly skilled rural residents (backwash)
Flows of political influence and government spending
Urban growth increases socio-political conflict, contributing to a policy promoting decentralization (spread)
Government expenditures enhance the infrastructure and public service delivery systems of the more heavily populated urban areas (backwash)

Source: Gaile (1980) in Barkley *et al*. (1996).

been virtually nil. Yet, social capital networks may affect rural landholder resource allocation decisions in various ways; consider three here: First, it is generally recognized that participation in social networks enhances access to information about commodity markets (e.g., crop prices), new production technology, and credit opportunities that likely influence land use decisions by landholders. However, the empirical research on these assumptions, especially as they pertain to urban variables, await further analysis: Such as crops designed for local urban consumption vs. national markets; low-cost/high-tech breeder technologies (e.g., analogue forestry), versus high-cost/low-tech tractor technologies, etc. Second, productive participation also enables cooperative activities (e.g., labor sharing) that can increase productivity of labor-intensive land uses. Third, social capital, once mobilized into collective action, can reduce the various risks of "going it alone" in pressing for policy

reforms or concessions from government institutions that have land use implications (e.g. the Landless Rural Workers movement—*Sem Terra*—in Brazil). Urban centers are often the spatial hubs of social capital networks that extend far beyond the geographic limits of the urban built environment. In other words, successful productive associations, may lead to dynamic political missions.

Three analytical challenges follow: First, how do we accurately conceptualize the nature of the causal relationships between landholder participation in social capital networks and distinct land use actions (e.g., direct vs. indirect, linear vs. non-linear, deterministic vs. probabilistic). Social capital networks are often spatially mobile and fluid. Land is fixed in space. What, then, are the spatial attributes of social capital networks?

Second, we presently lack an analytical definition of the essential components of the participative processes of social capital formation. Do all such processes share certain common characteristics that can be replicated in multiple geographic settings? If not, then any general model based on social capital theory would have constrained applicability. Finally, the main methodological problem for potential applications concerns the design of a methodology that will produce reliable quantifiable indicators of social capital impacts on discrete land use decisions. Perhaps, some of these challenges might be overcome by considering the potential applications of network theory.

Network exchange theory (NET)

Another stream of ideas that may fruitfully contribute to the conceptualization of a model of urban influences on rural landscapes derives from the work of sociologists interested in network exchange theory or NET (Willer, 1999; Friedkin, 1993; Emerson, 1976; Cook and Yamnagishi, 1992). We might adapt neoclassical economic theory (not to be confused with NET) to posit that land use decisions by individual agents (e.g., landowners) are influenced by social relationships that constitute structures of interaction among agents. In exchange networks, agents interact with each other seeking favorable resource outcomes and their success is conditioned by the type of connections between their own and others' positions within a network (Willer, 1999:196). Although initially NET began as a discourse on the construction of power relationships in organizations, several concepts from NET may be usefully applied to the analysis of urban influences on hinterlands. First, NET provides a structural framework (i.e., networks) to help explain human agent behavior. Those networks may be relatively simple (linear or stem) networks or evolve into more complex probability decision tree networks. The assumption here is that interactions among agents in a network influence land use decisions and, therefore, the nature of those networks and the relative strength of specific connections will likely effectuate distinctive land use outcomes. Of course networks are not isolated in space or fixed in time which suggests a second important concept, that of "network domains," the independent sub-networks in which exchange positions (or agents) are embedded. Some agents may be confined to single domain networks, while others are embedded in multi-domain networks (Willer, 1999:99). Third, the concept of "expected value probability" reflects a systematic effort to quantify and measure the likelihood of certain outcomes arising from network interactions. For example, the probability that active participation in a religious organization (network

domain) has a predetermined influence on land use decisions may be conditioned by an agent's participation in a political organization (network or domain) that draws members from that specific faith community.

The empirical challenge facing NET is in the matter of model specification. As a behavioral (rather than purely probabilistic) model, an analytical approach and method for defining and measuring probability factors for specific causal pathways remains somewhat elusive.

The urban-rural interface

Conceptually, the urban-rural interface (URI) is not simply understood in spatial terms, as a "peri-urban" zone or geographic interstice between the urban built environment and the rural landscape, but rather more broadly as an array of networks connecting urban agents and rural producers. I would distinguish this idea from Bradley's (1984) conception of the "urban/forest interface" (a largely spatial concept), by suggesting that social networks play a key role in defining the decision environment for rural producers who effectuate rural land cover change outcomes. Rural producers, for example, participate in productive economic networks, in part constituted by urban agents through whom they sell their products and obtain credits. They participate in political networks involving urban-based political parties and movements. Rural producers are also involved in various social capital networks (religious, civic, and filial) that connect them to urban centers. These various networks provide the scaffolding of the URI and are the conduits for various types of flows between urban and rural places: financial capital, social capital, labor, technology, and information flows. It is the interaction of these flows with each other and with endogenous factors at the household level (e.g., family labor, financial assets, property size, etc.) and exogenous forces (public policies, macroeconomic conditions, etc.) that I speculate will provide a more robust understanding of the processes leading to tropical deforestation and distinct land use patterns. The Urban-Rural Interface might also be defined as the land use "decision space" of rural producers, a 3-dimensional matrix or probability function within which different sets of land use decisions might be identified and ranked.

To illustrate how the URI mediates the process of rural land-use decision-making, a simplified 3-dimensional decision space schematic might be considered (figure 2). Plane/axis "X" represents a range of endogenous variables characterizing the household as a productive rural land-owning unit (e.g., household size, soil quality). Plane "Z" consists of factors that are exogenous to the URI but presumed to be influential in rural land use decisions (e.g., commodity prices, interest rate). And Plane "Y" is an array of elements associated with urban-based networks. Other networks that cut across the land use decision space (the urban-rural interface) might be superimposed on these axes (e.g., political networks, legal-institutional networks, information networks).

For the most part, the networks on plane "Y" are based in urban centers to provide an accessible, centralized location for interaction among network members and clients as well as provide opportunities for interaction with other urban-based networks (consistent with Thunian and gravity-based interpretations). Accordingly, they constitute the urban side of the urban-rural interface. However, these networks are not necessarily restricted to urban

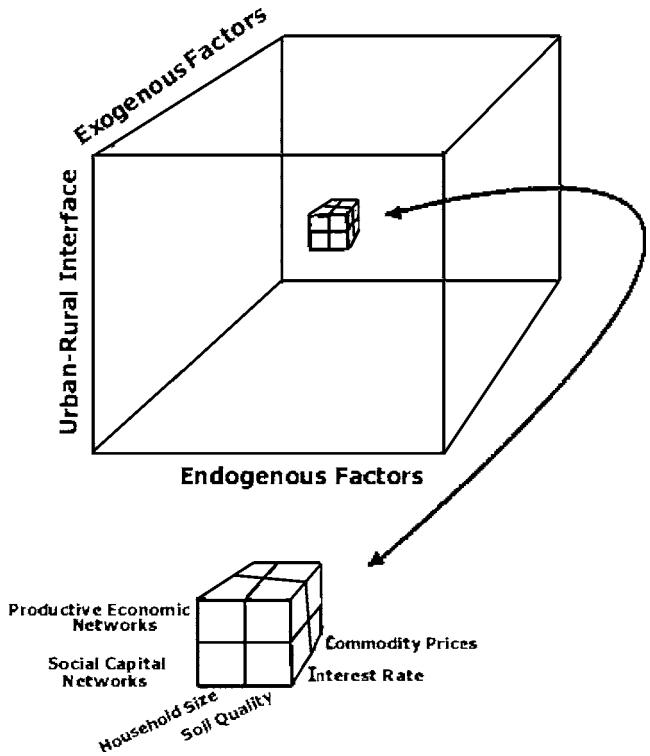

Figure 2. The urban-rural interface and landscape change, where "X" axis = endogenous factors, "Y" axis = URI, and "Z" axis = exogenous factors. *Source:* Adapted from Sanderson and Pritchard (1993).

centers. For example a producer cooperative will likely have a centralized warehouse in the urban center at which critical financial and information exchanges enter a disseminative social capital network. The same network may also include individual producers dwelling in rural areas who own trucks used to collect and transport member's produce to the warehouse. How the extension of each network into the rural space is hypothesized becomes an important and challenging task of specifying and applying a URI model.

In this illustration I distinguish between two types of urban-based networks: social capital networks and productive economic networks, "Social capital networks" generally refer to the collaborative labor organizations frequently found in civil society. The specific types of organizations that generate social capital for their participants will obviously vary among cultures. In Brazil, these would include rural workers unions, farmer cooperatives, the Landless Rural Workers Movement, women's producer coops, religious organizations, etc. Participation in such networks that generate social capital are hypothesized to influence the land use decisions of individual network participants in either positive or negative directions (in regards to deforestation). "Productive economic networks" emanate from the productive activities of the local urban economy and include both formal and informal (unregulated) economic activities (e.g., from urban employment to urban-based agricultural

service enterprises). Access to and participation in both types of urban-rural networks are likely to influence rural land-use decisions but will be influenced by both the endogenous characteristics of the rural producer household and exogenous forces originating from outside the URI as outlined in Table 4.[2]

While this simple 3-dimensional schematic may help us to visualize the general URI scaffold, the causal linkages between independent decision variables (situated in different social capital and productive economic network domains) and distinct land use outcomes remains to be specified. These linkages can be graphically represented within a network system (figure 3).

In this particular illustration, a multi-domain network system is represented. Exogenous domain variable "A" (declining corn prices, rising beef prices, for example) may directly influence farmer J's decision to convert his annual crop field into pasture. Endogenous domain variable "B" (e.g., increasing household size due to the arrival of new family members) might moderate the influence of the AJ signal toward pasture to maintain domestic food stocks for internal household consumption. However, a government sponsored credit program to promote rice production ("C") is channeled through a local urban bank ("D") that makes low-interest loans to qualified farmers who participate in an urban-based farmer cooperative ("E"). Farmer "J" is a member of this cooperative (situated in the inter-domain set of the Urban-Rural Interface and qualifies for this subsidized loan. His decision then to convert his corn-field to a rice-field rather than to pasture would not be accurately predicted from an analysis of the "A-J" dyad alone, which appears "economically rational". Nor would this land-use outcome be accurately predicted by the intra-domain dyad, "B-J" which, considered alone, would point toward a "demographically rational" corn-field land use option. Nor would the existence of a credit program for rice producers ("C-D") necessarily eventuate in a land use decision by farmer "J" to plant rice. Only when we consider the mediating influence of the farmer cooperative, in which "J" belongs, situated in Urban-Rural Interface, is the rice land use outcome (convert from beans to rice or clear new land for rice) plausible. Given the "situational rationality" of farmer "J" the switch from a corn to rice-based is logical. Rice can help supplement "J's" household's food needs, the production of which can be subsidized by a credit program. It is a rational utilitarian decision in the end, but only if the analyst considers the social network function provided through the URI.

While the urban-rural interface framework focuses on the interaction of urban-based networks with rural producer households having specific internal characteristics, an additional consideration is the influence that previous land use decisions have on current and future land use decisions. Any efficacious URI model, therefore, must be a dynamic iterative multivariate model with a temporal dimension that accounts for the accumulated effects of historic land use decisions. At this point it would be useful to regard "land use" as a sequential temporal process beginning with the decision of a rural producer to convert a forest area into one or more productive uses (plots). As the physical conditions of each plot for a chosen use changes over time, the rural producer may bring into production additional forest areas, abandoning the original plots to fallow. The challenge for the modeler is to estimate the probability that at any given time a specific configuration of network and household factors will generate particular land uses, a daunting challenge indeed.

Table 4. Selected variables defining the urban-rural interface

1. *Plane "Y": Urban-based networks*
Social capital networks
Producer marketing cooperatives
Social clubs
Voluntary benevolence associations
Local mutual assistance groups
Landless Rural Workers Movement (MST)
Faith communities/religious organizations
Political party organizations
Productive economic networks
Formal lending institutions
Informal credit cooperatives
Formal wage employment
Informal economic activity
Crop processing firms
Dairy processing firms
Slaughter houses
Machine repair services
2. *Plane "Z": Exogenous factors influencing land use decisions*
Crop prices
Farm input prices
Farm land prices
Subsidized rural credits
Interest rate
Consumer price index
Fiscal incentives (tax measures)
Climate factors (e.g., drought)
3. *Plane "X" endogenous rural producer characteristics*
Household composition
Land tenure
Rural property holdings
Urban property holdings
Initial household capital stock (fixed and liquid)
Initial household debt/capital ratio (degree of initial indebtedness)
Distance to market
Off-farm income
Producer educational level
Natural resources (soil quality, irrigable water supply, forest resources)

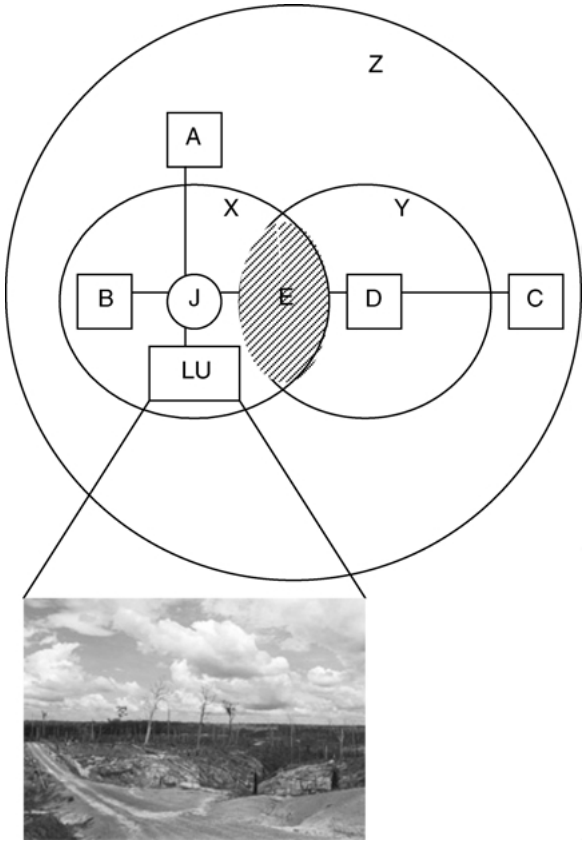

Figure 3. Multidomain network representing farmer land use decision tree.

Another consideration for an urban-rural interface model is the presumed nature of the relationships between variables within and between different networks. The strength of a relationship may be very strong, but indirect, perhaps magnified by the influence of an intervening variable. For example, a rural producer may obtain a government-subsidized loan to plant a specific crop. The farmer may plant the crop but fail to see it to harvest due to lack of adequate technical knowledge about crop management. The same farmer who also participates in a social capital network (e.g., farmers cooperative) may learn from other farmers the requisite management knowledge and the crop may succeed. In the former case, the failed crop may force the farmer into debt or to shift to a different land use strategy compatible with the household's existing knowledge. The often circuitous and multi-linear nature of the flows of any one network variable upon the final land use outcome points toward the potential utility of decision tree mapping to evaluate causal pathways in urban-rural interface analysis.

Yet another consideration is the affect that property turnover has on second and third-owner land use decisions. All properties eventually change land-owners and new land user's

arrive bringing with them a range of different values and different situational rationalities from the preceding land users. Incorporating this demographic dynamic into predictive land cover change models will be a critical component in determining their accuracy.

Finally, three principles should be considered in URI applied research. First, the influence of cities on their hinterlands will differ depending on the function of those cities in the larger regional, national and global systems of cities. Case study research focusing on one isolated city will doubtlessly fail to capture the range of influences emanating from different cities in the same or different city systems. For example, we found vastly different types of city systems in the "populist" frontier of Rondônia from the "corporatist" frontier of southern Pará, with somewhat different associated rural landscapes (Browder and Godfrey, 1997).

Second, the range of URI variables that might influence rural land use surrounding any given city system (and these may differ among city systems) are likely to be highly endo-interactive, requiring methodological controls for the effects of multi-colinearity. Simply inserting a discrete independent variable (e.g., farm distance to nearest urban center) into a linear regression model will likely fail to either produce any statistically significant result and certainly will underestimate the actual affects of urban factors on rural landscapes.

Third, advances in consumer-level communication technologies (satellite-based telecommunications systems) have widely spread to rural Amazonia, perhaps off-setting some of the distance-based (friction) effects impeding spatial interaction between urban and rural locations. Farmers can now directly observe commodity prices changes on the Chicago stock exchange over the internet and their satellite-linked television sets.

Conclusion

In this paper I raise the question of how we might understand and articulate the influences of urban centers on tropical deforestation and subsequent land use. This paper reviewed the enduring legacy of Von Thunen's concentric zones framework of agricultural land use and summarized the later contributions of growth pole theory and innovation diffusion research. Most of these works propose deterministic models building on the Thunian framework, and few include specific urbanization effects or disaggregate "urban influences" into discrete variables. Meanwhile, economists, demographers and political ecologists have attempted, from their respective perspectives, to explain the process of land use change without explicitly factoring the urbanization influences on rural land users, with generally disappointing results. Herein lies the challenge that this essay has sought to address through the rubric of the Urban-Rural Interface concept. The URI is seen as a field of interacting forces, some emanating from sources exogenous to the rural producer (e.g., commodity prices, interest rates, institutional rents), others emerging as constraints or characteristics internal to the rural property and its owners (e.g., household labor, soil quality). Many of the most important determinants of landscape change proceed through pathways mediated by the intervening urban-based networks in which rural producers participate. Several different networks could be identified; for illustrative simplicity I have selected two: economic productive networks and social capital networks. Having proposed a general conceptual framework here—the Urban-Rural Interface—I leave the task of formulating and testing such a model to another paper.

Notes

1. Kummer and Sham's analysis questions the findings of 7 other studies that emphasize the importance of population pressure as the dominant driving force of tropical forest decline. Those studies are: Allen and Barnes (1985), Grainger (1986), Lugo *et al.* (1981), Palo *et al.* (1987), Panayotou and Sungsuwan (1989), Reis and Margulis (1990), and Rudel (1989). Sambrook *et al.* (1999) also emphasize the importance of population growth. Other studies, however, suggest that other variables play a significant role in explaining deforestation: Kyle and Cunha (1992) stress macroeconomic factors, especially the role of national factor markets. Chomitz and Gray (1996) found market access, land quality and tenure status to be key determinants of agricultural land use. Browder (1985, 1988), Mahar (1989), Binswanger (1989), and Pfaff (1994) all focus public policies, development projects, and deforestation. Leonard (1989) and Deininger and Minten (1996) emphasize the connection between rural poverty and deforestation.
2. By "rural producer household" I do not intend to imply a nuclear farm family sharing a single dwelling. Rather, by household I refer to the owners of a given rural property who make decisions about its uses. Such occupants may constitute extended filial units, nuclear filial units, or non-related persons communally managing the property and they may be reside on or off-the property in question.

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