Reconciling Agency and Structure in Empirical Analysis: Smallholder Land Use in the Southern Yucatán, Mexico

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The agent-structure binary in human-environment relations has historically ascribed primacy to either decision-making agents or political-economic structures as the anthropogenic force driving landscape change. This binary has, in part, separated cultural and political ecology, despite important research weaving structure and agency in each of these and related subfields. The implications of approaching explanations of land use using this binary are illustrated systematically, drawing from empirical research on smallholder land use in the southern Yucatán of Mexico, a development frontier and environmental conservation region. The land-use strategies of mixed subsistence-market smallholder cultivators are explored through agent, structure, and integrated agent-structure models addressing parcel allocations to a suite of regionally evolving and/or extant land uses. The models are compared to illustrate what understanding is missed by a focus on either approach alone and what is gained by joining them. Results suggest that focusing on structure or agency alone may lead to inadequate and even erroneous characterizations of the variables that are of interest to the chosen approach. A sectorally disaggregated approach can identify suites of factors that drive particular land uses. *Key Words: cultural and political ecology, Mexico, land-change science, land use, regression models.*

Over the past century, human-environment research in geography has engaged both agency and structure in order to understand various problems involving the interactions between nature and society (Turner et al. 2003). For example, cultural ecology and risk-hazards research initially focused on the behavior of local agents to address these problems, whereas political ecology and vulnerability studies turned to political-economic structures. The promise of explanatory coherence offered by either focus was offset by the limitations on comprehensive understanding. This realization has subsequently reshaped cultural-political ecology and other human-environment geographies, including the newly minted land-change, vulnerability, and sustainability sciences, each of which seeks some level of integration of agency and structure.[1] Despite valuable contributions by each research interest, systematic, empirical, and quantitative analyses of agency versus structural factors are few in number, and much work remains to be done to understand the roles and relative importance of the two suites of factors as they vary in different geographic settings and production sectors, and the potential explanatory power that may be gained from their union. This article undertakes such an analysis through a study of land use in the tropical forest—agrarian frontier of the southern Yucatán of Mexico. It explores agent- and structure-based factors used to explain land-use allocations (cultivation) in the region and to comment on the questions raised above about the coupling of both sets of factors to understand human-environment problems.

Research Context and Problem

Different Versions of Agency and Structure

Cultural ecology emerged in the 1960s, influenced by themes of cultural adaptation in anthropology, the rise of the systems concept in science, and studies of peasant farmer rationales by Chayanov (1966) and Boserup (1965).[2] In large part, cultural ecology in geography constituted a response to the appeal by Brookfield (1964) that the landscape could not be understood without attention to the behavior of land managers, who, after all, are the critical agents modifying or transforming the landscape. This focus on the land manager as an actor and decision maker also paralleled the underlying premises in natural hazards research (Burton, Kates, and White 1978). Agent-based theory, largely consistent with economic concepts, became the explanatory pivot of the treatments of human-environ-

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ment problems entertained by these interests (e.g., Brookfield 1972; Turner and Brush 1987; Netting 1993).

In the 1980s, critical theorists challenged risk-hazards' emphasis on agency on the basis that such emphasis was unbalanced or produced incomplete and even erroneous answers to human-environment problems (Watts 1983a, 1983b). Risk-hazard problems required a major refocusing to address the role of societal structures (Hewitt 1983), a theme that was subsequently carried to research in cultural ecology (Brookfield 1984; Bassett 1988). This shift in explanatory emphasis would be labeled political ecology, with a distinctive subcluster engaged in vulnerability studies (Blaikie et al. 1994). For some initial practitioners (Blaikie and Brookfield 1987), political ecology searched for a union of agency and structure. The paucity of explanatory coherency and, foremost, the diminutive "political" component in this search according to some experts (Watts and Peet 1996) led to an early dominance of a structural political ecology and vulnerability studies (e.g., Blaikie et al. 1994; Bryant and Bailey 1997; Forsyth 2003). These human-environment geographies, in turn, were challenged as lacking an event- or agency-centered understanding (Vayda and Walters 1999). Subsequently, political ecology has taken many turns, including post-structural ones (e.g., Rocheleau, Thomas-Slayter, and Wangari 1996; Robbins 2004), which have been variously critiqued within the political community as overemphasizing the "social construction of nature" at the expense of attention to the material environmental manifestations of the social relations of production, or, the "natural construction of the social" (Watts and Peet 1996, 262–63).

By the turn of the century, these developments, in tandem with the emergence beyond geography of global environmental change and sustainability interests, helped to generate the land-change, vulnerability, and sustainability sciences (Cutter 2001; Kates et al. 2001; Turner 2002a, 2002b; Turner et al. 2003; Gutman et al. 2004; Liverman 2004; Turner, Geoghegan, and Foster 2004; Kasperson and Kasperson 2005).[3] These rapidly growing research themes also seek to address agency and structure, but do so through the lens of post-positivism, an explanatory perspective critiqued by many students of political ecology and vulnerability studies for a variety of reasons, such as its links to modernism and the inequities propagated by the modernist agenda, its claims of objectivity, and its insufficiency in revealing the complexities of processes and relationships of interest (e.g., Peet and Watts 1996; Forsyth 2003; Robbins 2004).[4] Differences in explanatory perspectives notwithstanding, the search for a union of agency and structure is evident within "hybrid" ecologies—expansive approaches to human-environment questions that attempt to bridge the questions and approaches of political ecology-vulnerability studies and land change-vulnerability-sustainability sciences—often employing an actor-conscious approach (e.g., Batterbury and Bebbington 1999; Turner et al. 2003; Vasquez-Leon and Liverman 2004; Zimmerer 2004; P. A. Walker 2005).

The utility of this union would appear to be as obvious as it has been difficult to achieve. Agents do not make decisions independent of the political economic conditions in which they exist and the cultural and historical experiences that give rise to path-dependent constraints on their options. These conditions and experiences shape the very essence of household behavior, and together with biophysical considerations, they mediate the decisions made. Likewise, these conditions are not immutable, and the household, being composed of reflexive agents, interprets and reshapes its circumstances, requiring attention to household decision logic relative to the observed outcomes. In some cases, external forces appear to overwhelm the household and elevate the role of structure in understanding the outcome of the coupled system. In others, the household displays considerable latitude in decision making, and the outcome cannot be understood absent attention to the household behavior. Comprehensive understanding, according to this claim, requires consideration of the agent-structure binary (e.g., Turner, Geoghegan, and Foster 2004).

Various human-environment interests are attempting to couple agency and structure by way of quantitative models (Zimmerer 2004). For example, land change research in greater Amazonia, mostly addressing deforestation, has examined cultivation practices and fallow dynamics as linked to, variously, household life cycles, tenure (institutional structure), and labor markets and external capital (economic structure) (Pichón 1997; Marquette 1998; McCracken et al. 1999; Coomes, Grimard, and Burt 2000; Evans et al. 2001; Perz and Walker 2002; R. Walker et al. 2002; Pan and Bilsborrow 2005). These works draw on household survey and other data to test the roles of household conditions, infrastructure, and various institutional, economic, and policy structures in land-use allocations and land-cover consequences (R. Walker and Homma 1996). Few, if any, of these works, however, address the range of structures embedded in the meaning of political economy, in part stymied by issues of systematic data relevant to the scale of analysis. Some works have tackled land change by political economic period, such as that on deforestation in Cameroon (Mertens et al. 2000), demonstrating swings in the rates of change by period. Even fewer works by human-environment geographers test different

models of agent and structural factors to assess their relative roles in explaining land change. Interestingly, Abizaid and Coomes (2004) come close to such an assessment in a study undertaken in the southern Yucatán, examining household and government factors as they determine household land uses and forest fallow. In so doing, Abizaid and Coomes undertake a household approach that remains as the mainstay of many variants of human-environment research within and beyond geography.[5] Zimmerer (2004) notes that household-focused studies have contributed fundamentally to developments in at least two thematic research fields: tropical forest change and agricultural intensification. Yet, both thematic areas and human-environment research in general continue to lack systematic, comparative analyses of household and structural factors.

The Research Problem

Absent meta-analysis and with few quantitative assessments of competing models, what evidence informs the human-environment geographies that a coupling of agency and structure will be fruitful? Will the coupling improve understanding and explanations of human-environment problems such as land use in tropical "frontier" settings? If so, exactly which combinations of structural and household factors are most important in determining land use, for which sectors? These concerns are examined here in an attempt to understand the land-use strategies of smallholder cultivators in the southern Yucatán. Specifically, smallholders' allocations of their land parcels to different uses in their portfolio are analyzed for hypothesized relationships to agency and structural factors as informed by or consistent with various explanations employed in the different human-environment geographies noted. Three statistical models (agency-only, structure-only, and unified structure-agency) explain variations in household land-use portfolio allocations and provide the empirical basis and backdrop for a consideration of the interplay of agency and structure in this rapidly transforming landscape. The results of the three models are compared to illustrate what understanding is missed by a focus on either dimension (or attendant theoretical focus) alone and what is gained by joining them. This means of analysis is post-positivist in kind inasmuch as it adheres to observable outcomes linked to general propositions about agency and structure through statistically tested relationships. It does not necessarily fulfill the different avenues by which all structural and constructivist approaches would address the problem.

The Southern Yucatán Region and the Problem Specification[6]

Regional History

From the late 1800s, Mexico has pursued different policies in regard to the use and development of the tropical forest lands of southern Yucatán (southwestern Quintana Roo and southeastern Campeche, Mexico; see Figure 1), focused in order on *chicle* (resin for chewing gum) and tropical hardwood extraction (Snook 1998), agricultural development, and conservation and archaeo-tourism (Klepeis and Turner 2001). An intensive period of state-sponsored settlement and large-scale agricultural schemes in the 1970s and 1980s rapidly increased the population of smallholders throughout the region and resultant land pressures, leading to such high rates of deforestation that the region made various lists of "hot spots" of tropical deforestation (Achard et al. 1998; FAO 1999). Annual rates of deforestation in the region (a study area of 15,900 km^2) as derived from satellite imagery, approximate 0.61 percent over 1987–1997, or 0.29 percent after adjusting for successional regrowth (Turner, Geoghegan, and Foster 2004, 131–32).[7]

Land Tenure and Use, Institutional Change, and Regional Environment-Development

The dominant land tenure in the region is represented by Mexico's communal *ejidos*, along with federal lands and a small proportion of private landholdings. Under Mexico's ejido structure, a group of smallholders registered as ejido members (*ejidatarios*) retain formal rights to a certain proportion of their community's land area and hold legal titles delineating that right. Most (but not all) ejidos in the region have distributed these land rights to ejidatarios in the form of parcels that are managed individually by the ejidatario households. The remaining land area in the ejido is considered to be collectively owned by the community. Some ejidos in the southern Yucatán also set aside ejido forest reserves for conservation and management for the extraction of timber and nontimber forest products (NTFPs).

In 1992, reforms to Article 21 of the Mexican constitution produced PROCEDE (*Programa de Certificación de Derechos Ejidales*—the Ejido Rights Certification Program), allowing ejidatarios to privatize (e.g., sell, mortgage) their share of their ejido lands if they so chose. In the southern Yucatán, these institutional transformations have been largely rejected by the majority of the region's ejidos, who entered into PROCEDE only to privatize their house lots, but not their (agricultural)

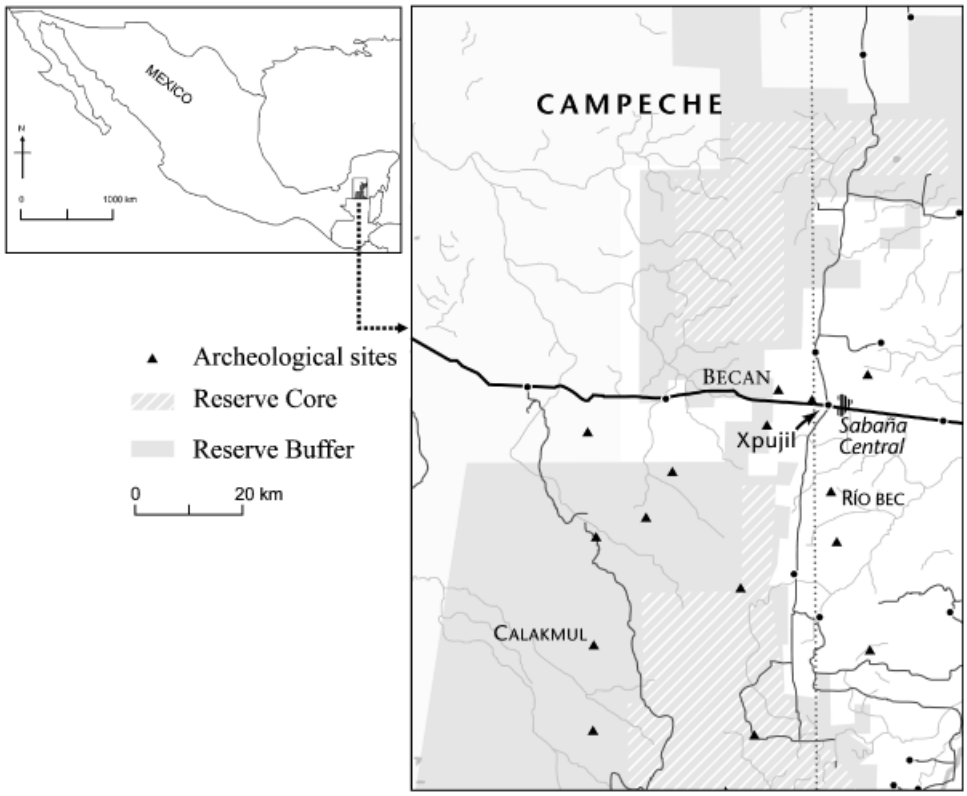

Figure 1. The study area (adapted from Roy Chowdhury 2003 and Turner, Geoghegan, and Foster 2004).

land parcels. Some ejidatarios and extension agents suggest that this decision follows from fear of taxation on the privatized parcel and concerns about the loss of overall community control over land and decisions. However, most of the region's ejidos have conducted an internal delineation of agricultural land parcels, often assisted by state-licensed surveyors. These parcels are, for the most part, managed by households as if they were private property, and may be inherited, rented, or even "sold" unofficially without titles. The data used in the analysis presented in this article were derived from two such internally parcelized ejidos.

In 1989, the Calakmul Biosphere Reserve (CBR), part of UNESCO's Man and the Biosphere program, was laid out over a large portion of southeastern Campeche in response to rising deforestation rates and international environmental attention (Primack et al. 1998). While 48.4 percent of the CBR is federally owned, most of its remaining land area (more than 49 percent) belongs to preestablished ejidos, where landscapes are in dynamic states of transition among mature and secondary forests and agricultural land uses (SEMARNAP 2000). In 1996, the municipality of Calakmul (Campeche) was formed and declared to be the nation's first "ecological" municipality, further testament to the rising primacy of environmental concerns in the region. Within Calakmul's *zona chilera*, a 3,300 km^2 area spanning the southeastern border of the CBR, 15.8 percent of extant forest fell between 1987 and 1997, primarily to enable commercial cultivation for chili (*jalapeño*: *Capsicum annuum* L.; Turner, Geoghegan, and Foster 2004, 133). Large areas across the entire Calakmul region have undergone secondary succession, and the focus of cultivated lands appears to be shifting to successional forests, other than currently cropped lands, indicating a potential shortening of fallow cycles (Lawrence et al. 2004).

The overwhelming cultivation strategy in the region is a form of swidden or slash-and-burn agriculture, locally known as *milpa*. Focused on maize, beans, and squash, milpa was originally predicated on substantial fallow periods after two to three years of summer wet season cultivation. In some cases, a winter emergency harvest (*tornamil*) of maize was undertaken. The length of fallow was related to household labor and land endowments, and the amount of land cultivated annually was increased by a government maize program to which most initial settlers contributed normal surplus. While maintaining milpas, farmers increasingly engage the market as dual or hybrid consumption and commodity producers (Keys 2004). Regardless of thin markets, modest capital inputs for chili production appear to intensify cultivation consistent with state designs, but not without biophysical

consequences that raise questions about the sustainability of the cropping practices used and the longer-term impacts on forest recovery (Peréz-Salicrup 2001; Lawrence and Foster 2002; Read and Lawrence 2003a, 2003b; Lawrence et al. 2004).

Ejidos and markets are not the only structures influencing land-use decisions. After the General Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA), Mexico also eliminated formerly guaranteed prices for staple crops in a first step to liberalize and modernize rural agriculture. To soften the blow to the vast rural sector dependent on those prices to secure livelihoods, the state instituted PROCAMPO (Programa de Apoyo Directo al Campo—Program for Direct Rural Assistance). PROCAMPO, in effect from 1994 to 2008, consists of payments to smallholders during one or two agricultural cycles (the main spring–summer cycle and in some cases an additional fall–winter cycle) based on the area cultivated by them in staple crops between 1989 and 1992. This structural policy aimed at the cultivation of staple crops (in this case, maize) has been linked to increasing deforestation rates as many farmers invest the payment into agricultural and pasture expansion (Klepeis and Vance 2003).[8]

In addition, the state introduced a diversity of credit and social reinvestment programs. *Alianza para el Campo* (Rural Alliance) is a broad umbrella of programs administered by the *Secretaría de Desarollo Rural* (SDR or Rural Development Secretariat) that promotes intensification and/or modernization to improve agricultural and nonagricultural income opportunities and the quality of life in rural areas. Alianza provides financing for food aid and capital investments in agriculture (farm machinery) and apiculture. It can also be used to finance materials for house construction and/or household appliances, such as sewing machines. Payments from the PROGRESA initiative (now *Oportunidades* under the Fox administration) are aimed at making education affordable and accessible, providing monetary assistance for school-going children and their mothers. The PRONASOL rural credit program (*Programa Nacional de Solidaridad*—National Solidarity Program) can be tapped for contingencies ranging from medical loans to the acquisition/rental of a tractor for mechanization.

These initiatives, along with the activities of local nongovernmental organizations (NGOs) and the CBR, influence ongoing local land use and environmental politics (Haenn 1999, 2002; Roy Chowdhury 2003, 71–84). Resultant land-use strategies include agricultural intensification through mechanization and/or increased cropping frequency by institutionalizing the tornamil or winter crop. They also include the cultivation of new market crops, pasture expansion, and a number of conservation-framed practices. Farmers have not been passive respondents to these developments. For example, independently of any sponsored program, they developed commercial chili production with intermediaries, such that it constitutes the most cash-productive cultivation in the region. Also, increasing numbers of farmers throughout the region have allocated lands for pasture to raise existing livestock, for speculation in future livestock investments, or to rent out to other farmers. Based on shared production/livelihood opportunities, farmers may form alliances within ejidos (locally, *sociedades,* such as those focused on cattle-raising or bean cultivation and marketing) or inter-ejido unions (such as the regional allspice producers, chili producers, or apiculture unions).

Most significantly, farmers have attempted to participate in the regional environmental politics of "green development" to reshape and explore income alternatives. The aim and challenge of conservation-based livelihood diversification in Calakmul is to generate enough income or production from environmentally friendly land uses to stabilize land use and curb the expansion of agricultural and pasture lands. At least two "green" land uses (green fertilizers, and agroforestry/reforestation on current/former agricultural plots) have been institutionalized in the municipality of Calakmul in Campeche, are promoted and assessed by extension agents, and are accompanied with small subsidy payments, seeds, saplings, and implements. Green fertilizers (leguminous plants, such as *Mucuna pruriens* (L.) DC. [velvet bean, or locally *nescafé*[9]] or *Canavalia ensiformis* (L.) DC. [Jack bean]) reinvent intercropping in the milpa to improve or prolong soil fertility, extend cultivation periods, and delay or defer fallowing and new forest cuts, thereby sedentarizing agriculture. These green land uses were institutionalized during the 1990s in programs run by state (e.g., Secretaría de Desarollo Rural—Rural Development Secretariat) and/or NGOs (e.g., Bosque Modelo Calakmul—Calakmul Model Forest). In the late 1990s the SDR subsidized the planting of green fertilizers through the *Roza-Pica-Siembra* (RPS, or slash-chop-plant) program as an alternative to slash-and-burn agriculture. Other incipient conservation land uses include extractive economies of NTFPs (e.g., apiculture and allspice), forestry, agroforestry and plantations of timber, and fruit and ornamental tree species.

These land-use strategies often constitute the means by which households manage to capture federal, state, and nongovernmental payments and subsidies, reimbursement for day labor, material inputs such as tree saplings for planting and pesticides, and extension programs. Individuals and communities, to varying degrees,

have engaged emerging programs and production opportunities, and begun to organize and tap local networks of information, credit, and extension. Before the municipality of Calakmul was formed in 1996, the regional alliance of ejidos, CRASX (*Consejo Regional Agropecuario y de Servicios de Xpujil*—Regional Agropastoral and Services Council of Xpujil), negotiated the entry of various environment-development projects in the region and, along with other emergent alliances, continues to represent ejidos in regional politics.

The Two Study Ejidos

The communities that are the focus of this study were selected for two reasons: (1) they are both located adjacent to the CBR's buffer zone along the reserve's southeastern and northeastern borders, respectively; and (2) they reflect different levels of total state funding for village development projects in recent years (1990–1999).[10]

The region in general experiences variable rainfall (900–1,400 mm annually), with a north–south rainfall gradient that generates a slightly longer and more intensive dry season for the northern ejido. Both ejidos possess upland mollisols (redzinas), relatively thin but good for cultivation, and seasonally inundated vertisols, typically avoided by farmers (Turner et al. 2001). Both ejidos were established by 1980, the southern one having been colonized largely by *mestizo* (mixed Indian and Spanish ancestry) immigrants from the state of Tabasco, and the northern one by Chol (Indian) immigrants from Chiapas. The two ejidos are comparable in terms of their total land area (the northern, ca. 4,340 ha and the southern, 3,979 ha), but vary in their assigned household entitlements (northern, 60 ha, and southern, 20 ha). Despite PROCEDE, both ejidos had opted for an internally (rather than officially) parcelized land tenure structure at the time of fieldwork, and households largely managed their parcels as if they owned them privately. The northern ejido experienced lower state investment during 1990–1999 and basic infrastructure, such as electric supply, was lacking there at the time field data were gathered. On average, levels of educational attainment are somewhat better in the southern ejido, which also has a secondary school where classes are televised; both ejidos have primary and kindergarten schools. Households in both communities have interacted to varying degrees with the structural-institutional programs mentioned in preceding sections, and maintain a range of land uses and economic activities in their parcels and beyond.

The Research Question Specified

Land use in the southern Yucatán has become increasingly dynamic and complex over the past two decades. Households have moved from primarily subsistence producers to mixed, subsistence-commercial producers. The state, markets, and NGOs shape different institutions that structure the conditions in which households allocate their production. Both agent-based models and structure-based models would appear to lend insights about parcel allocations and thus production and deforestation, among other important facets of the human-environment condition in the region. Indeed, Abizaid and Coomes (2004), Klepeis and Vance (2003), and Turner, Geoghegan, and Foster (2004) have found that various household variables, such as demographics and labor availability, and structural factors, such as PROCAMPO payments, are significantly related to crop/fallow holdings and deforestation. To date, however, no study in the many human-environment geographies has explicitly compared analytical frameworks to determine empirically the relative roles of those sets of factors embedded in household decision-making models and in structural models and the coupling of these two sets of approaches for understanding land use. We attempt such an assessment using a multiple equation regression modeling technique to analyze data drawn from two ejidos in the southern Yucatán.

Methods and Data

The data are derived from land-use surveys, including parcel sketch maps and use histories, and household interviews conducted in two ejidos during 2001–2002 that were not part of the initial SYPR project survey reported elsewhere (Turner et al. 2001). The units of analysis are smallholder households headed by individuals with ejidatario rights in their village ($N = 29$ households, including approximately 300 surveyed fields for both ejidos). Respondents were randomly selected from official rosters of ejidatarios, in order for the results to be representative of the villages' overall populations. Approximately 30 percent of registered ejidatarios in each village are represented in these data. *Pobladores*—households lacking ejidatario rights (about 3 percent of the households in the two villages)—were excluded from this analysis.[11]

In each ejido, survey and interview data allowed the compilation of variables describing household characteristics as well as variables recording each household's particular engagement with prevailing institutional structures (Table 1). The variables used here and their

Table 1. Data used in explanatory seemingly unrelated regression (SUR) models

Dependent (both models)	Independent (agency-based and joint models)	Independent (structure-based and joint models)
Hectares in milpa ("normal" summer cycle) Hectares in tornamil (additional winter crop of maize) Hectares in commercial chili Hectares in actual/ speculative pasture Hectares planted with green fertilizers or nescafé-milpa Hectares of "improved" fallows (under agroforestry/reforestation) Hectares in traditional fallows or secondary/ successional forest	Ethnicity • mestizo, indigenous (dummy var.) Tenure • Ejido (dummy var.) • Tenancy (number of years with land rights in current ejido) • Total land entitlement (ha in parcel, excluding houselot) Demographic • Family size (number effectively connected to household income) • Labor/consumer ratio Quality of life • Qualitative index constructed from 21 individual indicators (e.g., quality of house construction, appliances, electricity, potable water) Household economic strategy • Whether purchase or sell labor, or neither, or both (4 dummy vars.) • Net worth of livestock holdings (N$) • Household income from market chili in previous year (N$) • Number of off-farm direct wage sources tapped • Relative intensity and commercialization of household forest use (timber, fuelwood, NTFPs) (qualitative index) • Whether receive remittances or send payments, or neither, or both (4 dummy vars.)	Crop-based subsidies • PROCAMPO (summer and winter inscriptions in ha) Subsidies for "green" land use • Roza-pica-siembra (ha) • Agroforestry/reforestation (ha) Subsidies for quality-of-life improvement • Alianza and PROGRESA monies (appliances, infrastructure, education, food aid) (N$) Access to rural credit • PRONASOL loans (N$) Access to seasonal employment • Participation in government-sponsored temporal employment programs (dummy var.) Access to extension and information networks • Qualitative index of participation in workshops, receipts of plants, seeds and other inputs, orientation and technical assessment, whether promoter/presenter at workshops Access to regional social capital • Qualitative index of links to intra- or interejidal unions • Qualitative index of links to NTFP coops • Ejido (dummy var., proxy for state investment at the *ejido* level during 1990–1999)

Notes: PROCAMPO = Programa de Apoyo Directo al Campo (Program for Direct Rural Assistance); PRONASOL = Programa Nacional de Solidaridad (National Solidarity Program); NTFP = nontimber forest product.

assignment as "agent" or "structure" in kind follows from their use in household decision making and structural models as gleaned from the literature. Table 1 also lists cross-sectional data on land-use allocations in household land parcels as recorded in interviews and verified by sketch maps constructed in Global Positioning System (GPS)-assisted field visits. These data were analyzed using a multiple-equation regression technique detailed in the following sections.

Dependent Variables

The focus here is on land use at the scale of the household land parcel as allocated by or in the ejido. The seven dependent variables in the explanatory models were chosen for their relevance to local land-use decision making, agricultural intensification, environmental degradation, and conservation, and include hectares allocated to milpa, winter milpa (tornamil), chili, pasture, fallow successions, and reputed "sustainable" strategies, such as green fertilizers and plantations-agroforestry.[12] Extractive economic activities, involving chicle, allspice, apiculture, and wildlife management for tourism, among others, are commercialized in the region to varying degrees, and may be undertaken by households in community forests. We do not attempt to explain this extra-parcel utilization or that in household patio gardens for two reasons: (1) prevailing agricultural/conservation initiatives are aimed largely (though not exclusively) at land use in agricul-

tural parcels; and (2) it is relatively straightforward to quantify the areal extents of different land uses on parcels for modeling and spatial analysis. Forest extraction, however, may affect a household's overall economic strategies, including parcel-use decisions, and is thus recorded as an explanatory variable in the models.

Independent Variables

Agent-based household factors. Decision-making approaches examine farming behavior principally through the lens of those factors creating land-use demands (e.g., for agricultural intensification) to which the household responds, as mediated by environmental and societal factors (Turner and Brush 1987; Turner and Ali 1996; Laney 2002). Such models focus on the decision to allocate land, labor, and capital given household entitlements, controlling institutions, and so forth, and are predicated on the notion that households allocate and experiment with their resources in manners consistent with their self-interest. Agriculture and land-use change, therefore, is understood in terms of changes internal to households (even if affected from beyond) that affect demand or the means by which demand is met (e.g., changes in consumer-producer ratio, life-cycle of households, or farm gate prices). Given that these decisions involve land allocation or market factors, or both, these institutions, typically understood in many (structural) analyses, are also included in agent-based assessments. The explanatory variables chosen in this study represent factors in decision-making models that shape household perceptions of demand and lifestyle expectations. Relevant survey data pertain to household demographics, tenure, quality-of-life indicators, ethnicity, and household economic strategies, such as remittances, income from cash crops, participation in labor markets, and degree of dependence on forest products (Table 1).

Demographic and tenure variables are linked to consumption-production themes, shaping in part land and labor pressures. Household size and number of workers in a household are important for land-use decisions, and have received recent attention in studies of lifecycle impacts on land use (as described above). The agency and joint models in this article use a household's size as well as its labor-consumer ratio. The ratio is an indicator of labor supply relative to subsistence demand, and may register the propensity to undertake land investments over the long run (e.g., landesque capital). The ejido, an important land tenure institution in Mexico, influences household land allocation and use. All households in the dataset pertain to the same overall property regime (they are all ejidal households); a dummy variable identifies to which specific ejido each household belongs. Other tenure-related variables capture the number of years a farmer has had ejidatario rights and the amount of land to which he or she is entitled. A composite, quality-of-life indicator provides a metric of household wealth and lifestyle expectations, and encapsulates quality of the house/construction, availability of services such as electricity and plumbing, ownership of appliances, vehicles, and others.[13] Households' economic strategies reflect different aspirations and expectations, and ultimately the demand placed on their parcels; these strategies are captured by variables reflecting household forest extraction, off-farm activities (numbers of different sources of wage labor tapped), extra-household income or costs (receipt and/or sending of remittances), buying and selling farm labor, and any income from the sale of chili in the preceding year.[14] The last variable especially reflects the degree to which market cultivation affects parcel demands and is central to virtually all decision-making models of mixed subsistence-market farmers. Ethnicity is not commonly considered in agent-based studies but is added here because it may affect expectations, social capital, kinship-based labor sharing arrangements, or favored cultivation practices not captured in modeled variables.

Structural factors. Structural arguments focus on factors largely external to and beyond the management of the household (or community), those factors that control the larger rural economy (access to capital, land and resources) or that differentially empower and constrain farmers' decisions (e.g., Blaikie and Brookfield 1987; Bassett 1988; Zimmerer and Bassett 2003; Robbins 2004). Such factors tend to reside in political-economic structures, and attention is given to their origins and consequences. In the southern Yucatán, such broad-scale structures are twofold: comprising political-economic shifts in Mexican agricultural policy on the one hand, and the internationalization and intensification of conservation interest in the Maya forest on the other. The structural variables considered in this study capture households' experiences with agricultural, credit-based, and sustainable development programs and initiatives that increasingly affect resource access and impinge on individual land parcels. Although the market is an important structure, our study does not account for the mechanisms that determine farm-gate prices (national market and intermediaries) and real wages to the household. We instead recorded income generated from the sale of chili in the year prior to the interviews, and recorded it as an agency-based factor for the reason detailed earlier. It is noteworthy that the farm-gate price for

chili is virtually the same for all households as set by intermediaries' responses to the national market (Keys 2004).

The structural variables used in the analysis capture households' receipts of subsidies for particular land uses, their access to extension services and credit, and their links to certain measures of sociopolitical capital. They reflect to a large degree the engagement of households with the principal state and NGO structures attempting to influence land use in the region. The data on subsidies and credit were validated by records in government secretariats and local offices for extension and rural credit (Table 1). The number of hectares registered for annual PROCAMPO payments was recorded for each household. Households' receipts of subsidies for improvements in their quality of life and education (Alianza and PROGRESA described earlier) were recorded in "quality-of-life improvement subsidies." State and NGO subsidies received by households for nescafé-milpa (the RPS program) or agroforestry/reforestation on their parcels were recorded as hectares subsidized under each of those land uses. If households tapped the state rural credit program for loans at any time, the PRONASOL variable recorded the total amount borrowed. A dummy variable recorded household participation in seasonal employment programs administered by the state. Such programs are often offered during the dry season when farmers are not engaged in planting or harvests, and include archaeological excavations, clearing of ejido, reserve, or other boundary lines, and development projects.

Finally, several factors reflect and create the local and regional sociopolitical networks in which households are embedded, albeit to varying degrees. Such factors reveal aspects of social capital at the level of households and communities, affecting local organization and unions, access to extension and cooperatives such as those for nontimber forest products (NTFPs), and various institutional programs. Social capital has emerged in recent literature as a complex concept involving multiple forms of social relations, including trust, reciprocal arrangements, local networks and institutions, formal and informal organizations, and ties within and between communities or between communities and external structures (Fox 1996; Bebbington 1997; Bebbington and Perrault 1999; Mohan and Mohan 2002; Quibria 2003). Several authors have commented on the relevance of this complex concept for rural land clearance, use, and development (Bebbington 1997; Libby and Sharp 2003; Perrault 2004; Rodríguez and Pascual 2004), forest fire contagion (Simmons et al. 2004), resource management under diverse property rights regimes (Katz 2000), and environmental conservation and sustainable development (Pretty and Ward 2001; Pretty 2003; Rydin and Holman 2004; Jones 2005). Social capital may be viewed as an agent- or structural-based factor: households engage in creating their own social capital (e.g., social organization and networks), yet opportunities to enhance household or village sociopolitical capital by engaging local networks or external agencies and programs are determined by those entities (e.g., in which villages they operate). In this study, the variables that measure social capital are considered as structural factors because, to date, they have been entertained by studies variously labeled political ecology.

Paldam (2000) points out that social capital is best operationalized through multiple but related measures. Four variables captured aspects of social capital in this study. First, a qualitative index recorded farmers' access and use of extension services for agricultural and conservation land uses, capturing their participation in workshops and training, whether their plots received agents' inspections and recommendations, and whether they not only received extension but also provided such services to others in their community and beyond. The second and third qualitative variables reflect ejidatario (or household member) membership in one or more ejido producer societies and interejido unions, or in regional "green" cooperatives, respectively. The fourth is a dummy variable that specifies the ejido to which the household belongs. For the two ejidos in the study, this variable also serves as a proxy for another structural factor, namely their relative marginalization with respect to a decade of state-funded development projects (see above). The ejido dummy "0" refers to the northeastern ejido, which has received less attention than the southeastern one. Collectively, these four variables capture multiple, related aspects of local organizations, emerging networks and alliance-building between the state and communities through development projects, and are hypothesized to influence land-use allocations in household parcels.

Results: Exploring Differences in Household Land Uses

On average, households in the two ejidos had access to 59.31 ha of land, 22.53 ha of which they dedicated to seven land uses (Table 2): milpa (an average of 3.59 ha), tornamil (1.28 ha), chili (0.75 ha), pasture (1.72 ha), nescafé-milpa (0.91 ha), agroforestry and reforestation (1.31 ha), and secondary forest fallows (12.97 ha). These average figures belie significant variation among households across all land-use sectors, a result confirmed in

Table 2. Summary statistics for seemingly unrelated regression models of land allocation ($n = 29$)

Variable	Mean	Std. Dev.	Min	Max
Milpa (ha)	3.59	1.95	0.5	9.5
Tornamil (ha)	1.28	1.60	0	6
Chili (ha)	0.75	0.71	0	2.5
Pasture (ha)	1.72	3.91	0	12.5
Nescafé-milpa (ha)	0.91	0.95	0	3
Agroforestry/reforestation (improved) fallows (ha)	1.31	1.59	0	7.5
Traditional fallows (ha)	12.97	10.30	0	42
Native speaker of Spanish (mestizo) (dummy)	0.59	0.50	0	1
Tenancy (yrs)	15.00	6.02	8	25
Entitlement (ha)	59.31	13.61	40	80
Family size (no.)	6.34	2.44	2	11
Labor/consumer ratio	0.33	0.23	0.13	1
Only send monies (dummy)	0.07	0.26	0	1
Neither send monies nor receive remittances (dummy)	0.69	0.47	0	1
Both send and receive remittances (dummy)	0.17	0.38	0	1
Only receive remittances (dummy)	0.07	0.26	0	1
Neither buy nor sell labor (dummy)	0.14	0.35	0	1
Only sell labor (dummy)	0.24	0.44	0	1
Both sell and buy labor (dummy)	0.38	0.49	0	1
Only buy labor (dummy)	0.24	0.44	0	1
Net worth of livestock holdings (N$)	8153.28	24090.33	175	130595
Income from chili in past year (N$)	6566.90	8399.34	0	32400
Sources of off-farm wage income (qualitative index)	2.93	3.17	0	12
Intensity of forest use (qualitative index)	3.79	1.99	1	8
Total PROCAMPO inscription (ha)	4.36	2.03	1.5	9
Subsidized roza-pica-siembra (ha)	1.62	1.05	0	4
Subsidized agroforestry/reforestation (ha)	0.69	1.61	0	8
Quality-of-life improvement subsidies (N$)	4588.97	3508.93	0	8190
Total PRONASOL loans received (N$ 1990–99)	1051.72	646.21	0	2500
Access to extension services (qualitative index)	3.93	1.60	1	7
Links to intra/interejidal unions, municipality (qualitative index)	1.79	1.02	1	5
Links to NTFP cooperatives (qualitative index)	3.21	1.67	1	7
Seasonal employment programs (dummy)	0.66	0.48	0	1
Ejido (dummy)	0.45	0.51	0	1

Notes: PROCAMPO = Programa de Apoyo Directo al Campo (Program for Direct Rural Assistance); PRONASOL = Programa Nacional de Solidaridad (National Solidarity Program); NTFP = nontimber forest product.

other ejidos in the region for pasture, fallow forests, and agricultural crop use (Abizaid and Coomes 2004). Table 2 also denotes how households are notably different in their demography, wealth, and economic strategies, and in their engagement with prevailing structural forces.

Regression models are used to evaluate household and structural factors as independent variables based on their a priori roles in the basic theoretical frameworks favored by cultural and political ecologists. To account for the interdependence among land-use decisions, the analysis uses a multiple-equation modeling technique, Zellner's seemingly unrelated regression (SUR), that permits correlation of residuals among dependent variables (Zellner 1962, 1963; Greene 2003). Kennedy (1998) has detailed how the SUR technique can improve efficiency of estimates in situations where sets of equations are connected not because they are simultaneous equations but because they have contemporaneously correlated error terms.[15]

Three SUR models of land-use allocation are estimated: the first exclusively considering agency-based factors, the second solely examining structural factors, and a joint model that takes both structure and agency into account. Each model considers parcel area (in hectares) under each of seven candidate land uses as a function of the relevant independent variables.[16] Table 1 outlines the variables used in each SUR model, and Table 2 the summary statistics. It is important to note that although the approaches may deal with forces that originate and operate at different scales, their articulation is made possible by choosing the land-manager household as the unit of analysis. In addition, to evaluate the relative roles of agent- and structure-based independent variables in determining a given land use, the

joint model must be consulted—the agent-based and structural-based models cannot be directly compared per se. Although the split structure and agency models are informative for our purposes, the "real" relationships between a particular agent/structural-based factor and land use are found in the joint model because only the joint model controls for all the remaining agent-based and structural variables.

The results of the three models are detailed in Tables 3, 4, and 5. The joint model (Table 5) explores the effects of all agency- and structure-based variables on land-use allocations, but some independent variables are excluded to preserve sufficient degrees of freedom given the large number of independent variables and the relatively small sample size of twenty-nine households used in these model runs. For instance, the variables on household remittances and participation in seasonal employment programs are included in the agency and structural models, respectively, but excluded from the joint model. The discussion of the results focuses primarily on those variables holding strong statistical significance at the 1 percent level because of the large number of variables involved.

A comparison of the regression results (Tables 3, 4, and 5) indicates that the roles of individual factors (the signs of the estimated parameters of the independent variables) in the three models are not always consistent. These inconsistencies and the overall results are examined below by comparing each of the two (agency and structural) models to the joint model, focusing particularly on variable coefficients significant at the 1 percent level.

The Role of Agent-Based Factors (Agency and Joint Models)

Consistent with induced intensification themes, the agency-only model finds a strong positive relationship between area in milpa and family size (Table 3), ostensibly linking decisions regarding this largely subsistence activity to family demographic structure. Families with higher quality-of-life standards appear to be devoting significantly larger parcel area to subsistence cultivation. The same model also links area in market chili cultivation positively to family size and the labor/consumer ratio, suggesting the continued importance of household demand themes in market-crop decisions. Chili cultivation is reinforced by the previous year's chili-derived income, suggesting a market-like behavior strongly influenced by the most immediate farm-gate experience.

Table 3. Agency-based explanation of hectares in candidate land uses ($n = 29$, parameters = 17)

	Milpa	Tornamil	Chili	Pasture	Nescafé-milpa	Agroforestry, reforestation	Traditional fallows
	χ^2 73.52	χ^2 115.26	χ^2 188.40	χ^2 78.39	χ^2 50.40	χ^2 44.25	χ^2 197.98
	R^2 0.7171	R^2 0.7990	R^2 0.8666	R^2 0.7300	R^2 0.6348	R^2 0.6041	R^2 0.8722
Constant	−0.25	1.05	−3.17***	−1.34	1.05	−2.52	−0.84
Mestizo	0.62	1.75*	−4.58***	−0.34	−3.17***	−0.45	0.02
Tenancy	−0.21	0.48***	1.60	−0.66	0.98	2.72***	3.14***
Entitlement (ha)	−2.08**	−2.58	1.00	1.30	−3.22***	−0.50	0.97
Family size	2.88***	0.29	4.98***	0.49	2.71***	2.19**	−1.80*
Labor/consumer ratio	1.17	−0.57	4.54***	−0.41	2.73***	1.04	1.77*
Quality of life index	2.83***	−0.73	−1.18	0.79	1.10	1.80*	0.68
Only send monies	−1.11	−0.47	−2.82***	−0.14	−0.98	−0.90	1.60
Both send and receive remittances	−1.77*	−1.67*	−2.22**	−1.21	−3.20***	−0.77	1.37
Only receive remittances	−1.08	−0.75	0.57	−0.57	−0.49	−0.89	1.93*
Neither buy nor sell labor	0.54	1.20	−2.18**	0.29	0.96	−1.77*	−2.52**
Only sell labor	−2.27**	0.10	−2.70***	0.30	−0.78	−2.33**	−1.18
Only buy labor	−2.48**	−0.03	1.27	0.82	−2.04**	−3.11***	−1.88*
Net worth of livestock	1.76*	2.20**	−2.20**	2.13**	−0.66	−0.52	3.30***
Chili income last year	−0.91	−0.37	6.46***	2.14**	2.31**	1.18	1.57
Off-farm wage sources	1.29	0.23	1.92*	−1.00	−2.81***	1.16	1.16
Intensity of forest use	0.56	3.47***	−0.67	1.12	−0.81	−0.14	0.61
Ejido	−1.04	1.28	−2.02**	−0.00	−2.18**	−1.84*	−0.94

Note: Cells list standardized coefficients.
*$p = 0.10$, **$p = 0.05$, ***$p = 0.01$.

Table 4. Structure-based explanation of hectares in candidate land uses ($n = 27$, parameters = 10)

	Milpa	Tornamil	Chili	Pasture	Nescafé-milpa	Agroforestry, reforestation	Traditional fallows
	χ^2 36.57	χ^2 58.02	χ^2 46.92	χ^2 47.40	χ^2 76.74	χ^2 161.31	χ^2 36.62
	R^2 0.5577	R^2 0.6668	R^2 0.6180	R^2 0.6204	R^2 0.7257	R^2 0.8476	R^2 0.5580
Constant	0.22	− 1.38	1.33	0.91	− 0.53	1.25	1.77*
PROCAMPO	3.13***	1.21	0.43	0.20	− 0.78	− 1.36	2.13**
Subsidized roza-pica-siembra (ha)	0.52	− 1.44	3.76***	0.99	1.01	2.83***	1.06
Subsidized agroforestry/reforestation (ha)	0.97	0.22	0.15	1.53	0.57	6.02***	− 1.36
Quality-of-life improvement funds	1.49	1.74*	− 2.00**	0.32	3.02***	− 1.79*	− 2.17**
PRONASOL	0.32	1.04	− 2.03**	0.37	− 0.95	0.86	− 1.57
Access to extension services	− 1.88*	0.08	− 1.43	0.89	− 0.46	0.93	0.24
Links to intra/interejidal unions, municipality	1.80*	− 0.13	− 1.16	− 2.92***	− 4.28***	3.27***	0.73
Links to NTFP cooperatives	0.55	1.28	1.85*	− 0.16	3.46***	− 1.54	− 0.66
Ejido dummy (proxy for state investment)	− 0.76	1.53	1.80*	2.46**	2.25**	− 1.33	1.27
Seasonal employment programs	0.40	− 0.26	− 0.05	− 0.95	2.92***	− 3.11***	− 1.14

Notes: Cells list standardized coefficients. PROCAMPO = Programa de Apoyo Directo al Campo (Program for Direct Rural Assistance); PRONASOL = Programa Nacional de Solidaridad (National Solidarity Program); NTFP = nontimber forest product.
*$p = 0.10$, **$p = 0.05$, ***$p = 0.01$.

Table 5. Joint structure-agency model of hectares in candidate land uses ($n = 29$, parameters = 21)

	Milpa	Tornamil	Chili	Pasture	Nescafé-milpa	Agroforestry, reforestation	Traditional fallows
	χ^2 181.95	χ^2 236.74	χ^2 626.12	χ^2 224.96	χ^2 630.61	χ^2 887.58	χ^2 367.39
	R^2 0.8625	R^2 0.8909	R^2 0.9557	R^2 0.8858	R^2 0.9560	R^2 0.9684	R^2 0.9268
Constant	2.64***	0.71	− 0.33	− 0.91	6.66***	− 3.90***	− 1.66*
Mestizo	0.70	1.06	− 4.88***	0.94	− 2.09**	− 1.04	− 0.39
Tenancy	− 3.49***	− 2.00**	0.64	0.03	− 2.09**	− 0.42	4.95***
Entitlement (ha)	− 0.48	0.19	1.35	0.51	− 5.05***	4.17***	− 0.74
Family size	− 1.03	− 2.73***	− 1.45	1.28	− 4.23***	0.18	0.38
Labor/consumer ratio	− 2.23**	− 2.25**	− 0.00	0.90	0.33	1.73*	3.02***
Neither buy nor sell labor	2.47**	1.57	− 3.32***	1.55	1.94*	− 4.07***	− 2.66***
Only sell labor	0.74	0.83	− 0.04	0.29	3.31***	− 2.82***	− 0.60
Only buy labor	0.45	1.37	1.86*	0.29	− 2.84***	1.89*	− 4.05***
Net worth of livestock	3.45***	3.45***	2.52**	2.15**	4.56***	− 0.34	3.31***
Chili income last year	− 3.31***	− 0.39	5.59***	2.75***	1.82*	− 1.29	1.40
Off-farm wage sources	− 0.44	− 0.42	2.19**	1.59	− 2.98***	− 2.15**	1.21
Intensity of forest use	3.85***	3.54***	2.98***	1.72*	1.38	0.74	0.91
PROCAMPO	2.71***	0.92	2.06**	− 0.80	0.08	− 1.52	2.63***
Subsidized roza-pica-siembra (ha)	2.39**	0.38	2.78***	− 1.21	3.93***	1.29	0.04
Subsidized agroforestry/reforestation (ha)	1.40	0.06	− 0.62	3.85***	0.74	8.39***	− 1.32
Quality-of-life improvement funds	0.24	2.76***	2.95***	0.39	6.15***	0.20	− 1.33
PRONASOL	− 2.88***	− 0.21	− 1.62	1.22	− 1.27	1.30	0.02
Access to extension services	− 1.99**	− 0.41	− 5.18***	− 0.84	− 0.37	2.23**	− 0.68
Links to intra/interejidal unions	2.55**	1.10	1.32	− 4.15***	− 2.40**	4.25***	− 0.41
Links to NTFP cooperatives	− 0.82	0.92	2.04**	2.13**	3.05***	− 2.90***	0.03
Ejido dummy (proxy for state investment)	2.23**	1.82*	− 1.62	0.34	1.22	− 0.27	− 1.71*

Notes: Cells list standardized coefficients. Some variables in the joint model are excluded to maintain sufficient degrees of freedom. PROCAMPO = Programa de Apoyo Directo al Campo (Program for Direct Rural Assistance); PRONASOL = Programa Nacional de Solidaridad (National Solidarity Program); NTFP = nontimber forest product.
*$p = 0.10$, **$p = 0.05$, ***$p = 0.01$.

Households that only sell their labor (but do not hire it) plant significantly smaller areas in chili. In fact, chili farmers tend to hire labor at various times during the cultivation cycle, particularly during harvests (Keys 2004). Households that have to send monetary payments to family members outside the ejido also plant smaller areas in this cash crop, perhaps a function of the high risk associated with chili production. Interestingly, nonmestizo households (largely in the northern ejido outside the region's designated "chili belt" or *zona chilera*) cultivate larger holdings in chili, indicating the penetration of this market crop throughout the region.

The ethnicity variable proves statistically significant, indicating that, controlling for other internal household factors, nonmestizo households have larger chili and nescafé areas. The larger a household's land entitlement, the smaller its area in tornamil, perhaps because access to larger land area obviates the need for intensifying agricultural production by cultivating an additional winter maize crop. The positive relationship between tornamil and forest use is under investigation. As would be expected, pasture extent is linked directly to the net worth in household livestock holdings ($p = 0.05$). Pasture is also positively linked to the previous year's chili income ($p = 0.05$), indicating the possible investment of chili proceeds in this land use. Households that send and receive remittances, those that tap more off-farm wage income sources, and those that are mestizo tend to have smaller areas under nescafé-based sedentarization. The last result is consistent with the fact that many households in the largely mestizo community (ejido dummy also negative and significant at $p = 0.05$) opted out of nescafé use after initial experiments. Larger families with higher labor-consumer ratios that have smaller land entitlements have larger nescafé holdings. The longer a household has lived on or had access to its lands, the larger its actual agroforestry/reforestation holdings, a result confirmed by field observations in other ejidos in the region. Smaller agroforestry areas are held by households that either exclusively hire labor ($p = 0.01$) or sell it ($p = 0.05$), indicating that this land use appears linked to households that participate in labor markets to hire labor sometimes but also work for farm wages occasionally. Traditional fallow forest area, on the other hand, increases with households' tenancy in the ejido and their livestock holdings, presumably due to higher cumulative demand for maize and greater areas farmed through past years.

The joint model tests hypotheses regarding both agency and structural variables, and while it confirms some of the above results, it also contradicts others. Results of joint Wald tests indicate that the estimated coefficients of the agent-based variables in the joint model are significantly different from zero ($\chi^2 = 5816.89$, $df = 84$, $p = 0.0000$), indicating that factors capturing household agency in land decision making remain significant in explaining parcel land-use allocations, even after controlling for structural factors. The joint model confirms the agency-only model's findings about the relationships of chili allocation to ethnicity and previous year's chili income; pasture holdings to previous year's chili income and net worth of livestock; tornamil area to intensity of forest extractive use; nescafé area to off-farm wage income sources; and traditional fallows to length of tenancy and net worth of livestock. These relationships thus hold even when controlling for differential household engagement with structural forces.

Some important differences in explanation of land-use allocations exist, however, in the joint model. These differences may arise from additions/deletions (variable parameters significant in joint model that were not so in agency-only model, or vice versa) or contradictions (change of sign of estimated variable parameter between the two models). First, unlike the agency-only model, family size appears not to be a significant determinant of milpa plantings when structural factors are taken into account, and family size and labor-consumer ratios both appear to decrease tornamil plantings significantly. The household labor-consumer ratio is also negatively linked to allocations to the largely subsistence milpa (at the 5 percent level), possibly indicating a shift of focus to other (commercial) crops in households that have the labor to spare. These collective results, although counterintuitive, illustrate that when controlling for structural forces, demographic factors may no longer play the traditionally theorized roles in decision making, not even for subsistence production. They thus indicate the extent to which household economies in the southern Yucatán are complex and embedded in the regional political economy, and render suspect simple demand-based models of decision making.

Some other lessons are revealed by the joint model. For instance, the area cultivated in milpa decreases with length of tenancy (perhaps linked to household lifecycles) and previous year's chili income (a possible change of focus to chili production). These results are consistent with agency-based assumptions. All else being equal, the joint model confirms that sampled mestizo households have less land under chili, despite the fact that chili cultivation in the region began in the mestizo ejidos along the southeast border of the CBR. This result reflects the widespread speculation/investment in this market crop in the Chol ejido during the year that the

household surveys were conducted, despite the fact that this nonmestizo ejido was a late entrant to the chili producer market. The intensity of forest use was positively linked to tornamil extents in the agency-only model; the joint model also connects it to milpa and chili holdings. The reasons for the importance of this variable are under further investigation. Interviews with household members suggest that households continue to rely on timber and NTFPs as well as hunting as they extensify land use, indicating that agricultural investments may not completely substitute or eliminate dependence on forests.

The joint model finds that households that do not participate in labor markets and those that only purchase labor tend to have smaller areas in traditional fallows, suggesting that such households cultivated less extensive areas of land in past years (leading to less area in fallow forests by the time this study was conducted). In the joint model, household labor-consumer ratios are strongly, positively linked to area currently under traditional fallow forests—a relationship only weakly supported ($p = 0.10$) by the agency-only model. Even though the joint model suggests that labor-consumer ratios are currently linked to less area under milpa, this relationship may well have been different in the past—higher demand for maize for household consumption and/or animal feed in past years could have led to more cultivation of milpa in those years, resulting in larger areas of recovering fallows currently. Both models agree that longer tenancy and higher livestock investments increase the area in traditional fallows, presumably due to greater areas farmed at some point (cumulative through the years, or driven by livestock demand for feed/pasture) and then fallowed.

The two institutionally endorsed activities of nescafé-milpa and agroforestry/reforestation display a number of significant relationships with the theorized household factors in the joint model. Households with diverse sources of off-farm wages may be less poor or less dependent on agricultural incomes, or both, and do not invest in nescafé-based sedentarization or agroforestry/reforestation. On the other hand, poorer households tend to be less capable of purchasing labor, and, instead, either sell their labor or do not participate in labor markets. Such labor strategies (sell labor or no participation) are related to larger nescafé holdings, for reasons relating to structural issues noted below. Livestock investment also significantly increases nescafé area. As with the agency-only findings, mestizo ethnicity is inversely linked to nescafé area. The joint model also confirms the agency model's finding that entitlement is negatively linked to nescafé use, suggesting that with less (total) land to fallow, more attention is given to nitrogen-fixing legumes (land-abundant households are less likely to adopt such sedentarization practices). On the other hand, increasing family size, suggested by the agency-only model to increase nescafé area, is actually found to decrease it significantly when structural variables are controlled (in the joint model)—possibly for reasons linked to household life-cycles. Area in agroforestry/reforestation, in contrast, is positively related to land entitlement, suggesting that access to larger total areas of fallows enhances engagement with this experiment. Its negative relationship with nonparticipation in labor markets, exclusively labor-selling households, and off-farm wages indicates that poorer households (that only sell labor) are also less tapped into reforestation activities, and that more off-farm income alternatives lead to lesser areas of improved fallows.

The Role of Structural Factors (Structure and Joint Models)

The structural factors used (cf. Table 1) are consistent with those explored under the label of political ecology in that they originate from beyond the farm household as part of various political economic structures, engage farmers through sociopolitical organization, direct state payments, subsidies, and other initiatives, and, until recently, were not typically incorporated in decision-making models of agricultural change. According to the structural model, area in milpa and tornamil increases with increasing inscriptions in PROCAMPO. The tornamil result is not significant however, likely because payments for milpa (summer cycle PROCAMPO) and tornamil (winter cycle PROCAMPO) were not disaggregated in this analysis. RPS participation increases area allocated to chili, reflecting a diversification of strategies of chili farmers given a volatile chili market, which also affects the ability to repay and thus receive PRONASOL loans (negative relationship with chili at the 5 percent level). Increasing links to intra- and inter-ejidal unions reduce pasture investment, a result under investigation.

As expected, the "green" land uses of nescafé-milpa and improved fallows are strongly and positively related to structural factors but in complex ways. Interestingly, the structural model fails to find a statistically significant relationship between institutional subsidies to households for nescafé plantings (RPS variable), and the households' actual nescafé area. This result is unexpected and contradicts the researchers' observation and a commonly understood local reality that use of nescafé almost invariably depends on a connection to institu-

tional conservation programs and monies. Households with larger nescafé areas also appear to tap state-run seasonal employment programs, some of which "employ" farmers in either nonfarm activities or in the preparation of plots for sedentarization. Nescafé area appears positively linked to state payments and subsidies for improvements in the general quality of life, and to households' links to regional NTFP cooperatives, indicating that households that engage in such networks also tend to invest in "green" sedentarization land uses. Increased links to unions lower area in nescafé, a result that likely follows from the fact that this variable includes membership in the regional council of ejidos, an institution that has played an important role in promoting a broad range of income diversification alternatives but has not specifically focused on nescafé.

As hypothesized, parcel holdings of agroforestry and reforestation are strongly and positively related to inscriptions in NGO-subsidized projects for those uses. Such improved fallows are also linked to RPS program inscriptions—while RPS specifically subsidizes nescafé, the program also accommodates registration, subsidies, and other inputs for reforestation in fallow forests. Agroforestry and reforestation programs were vigorously supported by CRASX in the mid-1990s, leading to the positive relationship between links to ejido unions and improved fallows. Traditional fallow area does not appear to be strongly determined by structural factors (no structural variables significant at the 1 percent level in the structural model), although PROCAMPO subsidies seem to increase fallow area, whereas quality-of-life improvement subsidies decrease it ($p = 0.05$). A partial explanation may rest in the shifting nature of cultivation in the region: households that received PROCAMPO payments for a fixed number of hectares since 1994 have not typically farmed a spatially fixed plot. Instead, their (subsidized) shifting cultivation over time produces fallow forests in one or more locations in their parcels, generating a dynamic that could explain the link between PROCAMPO payments and secondary forests.

Again, the joint model confirms some of the structural model, but several major discrepancies are apparent. Results of joint Wald tests indicate that the estimated coefficients of the structural variables in the joint model are significantly different from zero ($\chi^2 = 5505.20$, $df = 56$, $p = 0.0000$), indicating that structural factors in the region are significant in explaining land use in parcels even after controlling for variation in household agency. The joint model reaffirms the structural model in that larger PROCAMPO subsidies are linked to larger areas in milpa. In the joint model, however, milpa extent has a negative relationship with PRONASOL—a relationship that the structural model failed to reveal. PRONASOL loans are commonly taken for various reasons related to household needs beyond agriculture, and it is possible that less well-to-do households with less land in milpa rely more on them. The joint model also fails to find any significant relationship between PRONASOL loans and chili area, unlike the structural model. Consistent with the structural model, area planted in chili holds a positive relationship with RPS for the reasons noted (and with PROCAMPO at the 5 percent level, indicating synergy between milpa and chili regarding plot rotations). The joint model contradicts the structural model in finding that chili is linked positively with quality-of-life improvement subsidies, suggesting that such funds may be directed to chili-related activities, such as purchasing pesticide-spraying equipment. Extension services appear negatively linked to chili, due to the fact that many of the extension programs focus on "sustainable" land uses as defined by the state and NGOs, and chili is farmer initiated. The structural model failed to uncover any significant structural factors behind tornamil planting. The joint model finds that tornamil is positively correlated with government subsidies destined for quality-of-life improvements, a result whose significance is under investigation. There is weak evidence in the joint model ($p = 0.1$) that this land use is more extensive in the southern ejido, a fact supported by field observations in that ejido of greater numbers of farmer inscriptions in winter cycle PROCAMPO payments (not disaggregated in this analysis). Inscriptions in agroforestry/reforestation programs significantly increase holdings in pasture, suggesting that such "green" subsidies may have the secondary effect of provoking expansionist land uses (see Klepeis and Vance 2003). Interestingly, larger pasture holdings correspond to households with fewer established links to ejido unions, at least in the two ejidos examined.

Unlike the structural model, the joint model shows that the quantity of land planted with nescafé is strongly structurally determined (Table 5), correctly identifying the highly significant relationship between the RPS program (designed to incorporate nescafé) and nescafé use in the region, and the top-down direction of this "green" land-use activity in the region. Other significant variables that are also consistent with the structural model include quality-of-life improvement subsidies and links to NTFP cooperatives (both positive), and the negative correlation between links to unions and area in nescafé. As with the structural model, the joint analysis identifies agroforestry and reforestation programs and links to unions as increasing area under improved fal-

lows. Unlike the structural model however, the joint model results show that a household's links to NTFP cooperatives significantly reduce area under improved fallows (a relationship negative but not significant in the structural model). This result implies that the majority of managed fallows are not mature enough to benefit from local NTFP cooperatives, or that household links to such cooperatives are predicated on products extracted from primary or traditional successional forests rather than from improved fallow forests.

Discussion and Conclusion

Much of the distinction between agent and structural interests in human-environment geography is registered by the emphasis given to household decision making (choice) versus socioeconomic and political structures (usually portrayed as constraints on choice). Recent practitioners operating under various research labels have recognized the importance of, and to various degrees have attempted, a more integrated vision of agency and structure. Still, very little attention has been given to systematic demonstration of the precise failures of fractional visions or what understanding may be revealed in their joining.

The brief exercise here attempts to illustrate quantitatively through one case study from the southern Yucatán that narrowing the focus to either agency or structure changes the explanatory relationships revealed in different land uses, and in some cases generates different, even misleading, results. The case in question compares two relatively new communities established along the border of the CBR in a frontier economy. Households in both ejidos engage in a number of land-use practices with the dual intent of self-provisioning (subsistence) maize and increasing income from (commercial) chili and other forest products. The households and communities differ in their ethnicity, tenancy, average land holdings, and demographic characteristics, as well as in their participation in the market, government and NGO programs, and union cooperatives, and in their access to social capital. These differences translate into different portfolios of land use and household well being.

The regression analyses indicate that smallholder agency accounts for a large proportion of overall explained variance in land allocated to mainstream agricultural uses: milpa (72 percent), tornamil (80 percent), chili (87 percent), pasture (73 percent), and "natural" forest fallows (87 percent). Of the new suite of diversified land uses in the region, approximately 73 percent of the explained variance in nescafé-milpas and 85 percent in improved fallows through agroforestry/reforestation are captured by structural variables alone, indicating the importance of broad sociopolitical forces in promoting such activities.

The model results should not be surprising and are consistent with the conditions in which the region's farmers operate—as quasi-subsistence or market farmers seeking to juggle production strategies to maintain consumption needs while expanding market income and experimenting with many options to achieve this aim. Consumption and market production decisions are consistent with agent-based theory in terms of the role of household and market conditions on land-use allocations, and have been demonstrated by way of econometric analysis for the region (Vance and Geoghegan 2002; Turner, Geoghegan, and Foster 2004). These conditions, however, are increasingly affected by a suite of institutions and agency programs operating directly on household endowments and introducing new opportunities. In some cases, agent- and structure-based factors reinforce one another, but in others they exert opposite influences on smallholder land uses. Pursuing agent- and structural models alone or unaltered by consideration of the factors of the other would miss these reinforcing and countervailing dynamics, suggesting that much more attention should be given to the coupling factors championed in each modeling domain and to exploring the explanatory union.

A major lesson from the results of this study is that focusing on structure or agency alone may fail to characterize correctly those variables that are of interest to the chosen approach. Thus, a structure-only analysis misinterprets the relationship of land-use decisions to certain structural factors or the significance of those factors, or both. Examples of relations that are misinterpreted or improperly emphasized include those between subsistence and market cultivation, and rural credit and state subsidies for education and quality-of-life improvements; between nescafé use and the state-subsidized RPS program; and between improved fallows and NTFP cooperatives. The agency-only approach, in turn, misidentifies the connection between land-use decisions and certain agency-specific factors—foremost, household size and its relationship to subsistence, market, and "green" land uses. Both orientations reduce complexity by narrowing their focus, potentially identifying base elements of land-use dynamics but also potentially leading to erroneous results.

This challenge does not negate the usefulness of either modeling approach alone. The relative roles of political-institutional structure and individual agency vary in complicated ways depending on the production sector, and focused treatments help to unmask the

interactions. For instance, cultivation of the traditional milpa (largely subsistence) is explained well by the demography, land entitlements, and PROCAMPO inscriptions of the farming household. The same factors, however, appear insignificant in pasture allocations, which are more closely tied to recent experiences with the chili market and social capital. Recent work (e.g., Laney 2002) suggests how internal differentiation within production systems can be "missed" by aggregate approaches to land-use and land-cover studies. Our results demonstrate how a sectorally disaggregate approach identifies more accurately suites of agency and structural factors that drive particular land uses, albeit in complicated ways.

Finally, the data and results support the claim that the southern Yucatán is transitioning from a frontier economy. The region is increasingly drawn into national markets for commercial chili, it experiences local land speculation in the form of expanding pasture holdings, and it may be moving toward commercializing timber and NTFPs in a more sustained way than during its "extractive" past (for Mexico at large, see Klooster 2003). In addition, the reach of the global is truly present in the form of international environmental arrangements (e.g., the CBR and the emerging MesoAmerican Biological Corridor) and capital-intensive regional development projects, such as El Mundo Maya. In the face of such dynamism, smallholders increasingly diversify their land-use portfolios to capture new livelihood opportunities as well as to spread risks as land conflicts intensify (Abizaid and Coomes 2004). Increasing numbers of these opportunities, especially those considered "green" and compatible with supraregional visions, are linked to the various institutions and agencies that offer relevant payments and subsidies. The analysis presented here suggests that some of those "greening" approaches will not sustain the environmentally friendly land uses they promote if they continue to operate on a subsidy basis without linking to other critical elements that reinforce such land uses—namely, extension programs, interejido unions, and network building. Beyond the schisms of cultural and political ecology addressed here, the findings of this study reveal some implications of policy prescriptions in landscapes similar to the southern Yucatán, where conflicting visions of development prevail. Such policies are likely to fail if they do not account for the complexities of factors to which farming households respond.

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Notes

1. For reviews of the different human-environment geographies noted here, see Hewitt (1983), Butzer (1989), Mitchell (1989), Blaikie et al. (1994), Zimmerer (1996), Cutter (2001), Kates et al. (2001), Zimmerer and Bassett (2003), Gutman et al. (2004), Liverman, Yarnal, and Turner (2004), Robbins (2004), and Kasperson and Kasperson (2005).
2. Cultural ecology in anthropology and in geography were not necessarily similar in interest and practice. That in anthropology sought understanding of material culture, that in geography of the landscape. More important, geographers never accepted the Stewardian vision of cultural ecology, which subsequently would be viewed as quasi-deterministic regarding environmental influences on material culture (Ellen 1982). Rather, geographers tended to view the human-environment relationships as synergistic, akin to the vision held by such anthropologists as Barlett (1980), Netting (1993), and Stone (1996).
3. Exemplars of these interests, commonly referred to as integrated environmental sciences, are numerous, as illustrated by the Intergovernmental Panel on Climate Change (McCarthy et al. 2001); International Geosphere-Biosphere Programme and International Human Dimensions Programme (e.g., IGBP-IHDP 1995, 2005); Millennium Ecosystem Assessment (MEA 2003); and the Resilience Alliance (Gunderson and Holling 2002). Also see Kates et al. (2001) and NRC (1999).
4. Post-positivism refers to one of the three principal explanatory perspectives identified within the philosophy of science. The others are structural and constructivist perspectives (e.g., Guba 1990). In our estimation, the land-change, vulnerability, and sustainability sciences and what was once labeled cultural ecology (but see Zimmerer 2004) operate within the dimensions of post-positivism, whereas political ecology and vulnerability studies largely adhere to various dimensions of the other two perspectives. Post-positivism and structuralism share an ontology of a real world with processes to be discovered. In this sense, some critical theorists are wary of "branches of poststructural and ecological thought which abandon reason and science as guides to human action" (Watts and Peet 1996, 261).

5. Zimmerer's (2004) recent review refers to work of this kind as cultural ecology, whereas we label it land-change science. We prefer the last term for two reasons. First, we can identify few current works by geographers that are self-labeled cultural ecology, despite the existence of the AAG's Cultural and Political Ecology (CAPE) Specialty Group and the substantial proportion of its membership that, we suspect, would not wish to drop the term cultural from its title. Second, a large portion of the research in question is generated by geographers not party to CAPE and by nongeographers who do not identify with either cultural or political ecology (e.g., Gutman et al. 2004). We concur with the content of Zimmerer's review; our differences are in the labeling of genre of research.
6. This review is taken largely from various works by the Southern Yucatán Peninsular Region (SYPR) project and its members. Readers are directed to Turner et al. (2001) and Turner, Geoghegan, and Foster (2004) for details. Throughout this article, all individual chapters of the latter publication are not cited; they can be consulted regarding the details and attribution of specific research contributions.
7. From 1987 to 2000, forest fragmentation increased 107 percent, forest edge density rose from 1.5 percent to 3.14 percent, and mean forest compactness decreased (Lawrence et al. 2004, 281).
8. The land uses eligible for PROCAMPO payments have since been expanded to include nonstaple crop systems, including agroforestry and forest plantations.
9. The local usage of the name *nescafé* to connote the leguminous (green fertilizer) *Mucuna pruriens* should not be confused with the internationally known coffee brand produced by the Nestlé company.
10. Such government projects could include village-scale infrastructure construction, food, education, and other aid, and investments for agriculture and conservation. These village-level data were derived from a comprehensive review of records of government secretariats, NGOs, and community organizations, and from interviews with institutional representatives in both Calakmul and the state capital in Campeche City. After compiling data for all possible ejidos in Calakmul, the ejidos were stratified into three groups of relatively high, medium, and low total state investment during 1990–1999. In order to study land use by households in the buffer zone of the CBR, one ejido was chosen from each investment class, and two of the resulting three ejidos chosen are the focus of this article. These two reflect medium (southern ejido) and low (northern ejido) levels of state investment. The ejido chosen from the highest investment class is not included in this analysis because (1) its land tenure arrangements are fundamentally different from the parcelization followed by the other two and (2) it is the recipient of major investment in community forestry—the dynamics of forestry and other land uses in the region's large forestry ejidos merit separate treatment.
11. Pobladores may be granted permission to farm temporarily on ejido lands, their assigned plots sometimes being relatively inaccessible or of marginal quality or both. They were excluded from this analysis, but will be explored in future research.
12. The empirical evidence that green fertilizers, such as nescafé, significantly reduce soil nutrient losses and that agroforestry is profitable, both as practiced by local farmers, is not yet established, although various agencies sponsor these activities.
13. A cumulative index, derived from the summation of binary (0/1) indicators reflecting whether the house had electricity and/or plumbing, potable water, latrine, walls made of concrete, wood, or mud, and/or floors made from the same materials; ownership of a chainsaw; ownership of a bicycle and/or a car or truck; ownership of appliances, including radio, television, gas/kerosene cooking stove, blender, refrigerator, sewing machine, and washing machine (a one-time state subsidy introduced a number of the last two appliances in selected ejidos).
14. Four dummy variables (send/receive/both/neither) captured each household's experiences with remittances, three of those dummy variables were included in the models in order to avoid multicollinearity. Similarly, four dummy variables (buy/sell/both/neither) captured households' strategies regarding the purchase and sale of labor for farm activities, three of those dummy variables were included in the models in order to avoid multicollinearity.
15. Other approaches, such as hierarchical linear models (HLMs) and multilevel modeling, have dealt with situations where there may be two or more basic units of analysis (e.g., workers within firms, students within schools, counties within districts, or, if applied to a general Yucatán context, ejidatario households within ejidos), and variables measured at those two (or more) different scales to capture processes occurring at those scales (Polsky and Easterling 2001; Bryk and Raudenbush 2002). In the example of HLMs for households and ejidos, ejido-level variables would have the same value for each ejidatario household within an ejido. In this study, however, the household agency-specific variables do not nest within the structural variables; *both* sets of variables are measured at the level of the household: the unit of analysis. The structural variables reported here capture *a household's particular link to* processes extending to or originating in sociopolitical structures at or beyond the level of the ejido. Those structural variables thus hold different values for different households, *even within the same ejido*. The particular dataset analyzed in this study does not subscribe to the type of nesting required in hierarchical statistical approaches. HLMs nevertheless remain an important avenue of research for understanding land-use choices in the southern Yucatán, particularly in analyzing household data nested within variables specifically captured at the ejido scale.
16. Additional model runs explored the seven land uses as percentages of total parcel entitlement rather than total hectares. These results yielded similar signs and magnitudes for estimated coefficients of most explanatory variables, though the significance of parameter estimates varied for some land uses and explanatory variables. These results are available upon request.

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