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ORIGINAL ARTICLE

Agricultural livelihood transition in the southern Yucatán region: diverging paths and their accompanying land changes

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Abstract Land change science has demonstrated that rural livelihoods around the world both drive and reflect changing environmental regimes and political economic/structural transformations. This article explores the relationship between increasingly globalized rural livelihoods and in-place land change, assessing results from social surveys of smallholding households in the southern Yucatán region. We examine evidence for a transition in agricultural livelihood strategies as smallholders adjust to changing political economic and institutional conditions, and link these transitioning strategies to land use changes. Based on household surveys in 1997 and 2003, we comparatively assess both changes in the selection of livelihood strategies and in the land use and cover impacts of those strategies. Our results indicate that although impacts of given strategies have changed little over this period, there are increasing proportions of households pursuing two divergent adjustment paths—one of agricultural withdrawal and one of agricultural intensification and commercialization. We investigate what sociodemographic characteristics differentiate the groups of households following distinct livelihood strategies. Our findings point to the possibility of simultaneous and contradictory land change outcomes as smallholders adjust in different ways to their intensified incorporation into global economies.

Keywords Livelihoods · Agriculture · Mexico · Land use · Land change · Migration

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Introduction

Current processes of global environmental and land cover change are both driven by and fundamentally affect local populations and socioeconomic structures. Numerous studies in the science of land change have highlighted the role of local agents and institutions in widespread land use change and broader ecosystem transformations. Local land management has been implicated in changing forest species diversity patterns (Lugo 1997; Michon et al. 2007; Rendon-Carmona et al. 2009), soil erosion and altered hydrological regimes (Mati et al. 2008), dryland degradation (Enfors and Gordon 2007), coastal ecosystem deterioration (Clarke et al. 2008), and other environmental transformations. While the role of local land managers in driving landscape and larger environmental change is undeniable (e.g., Carr 2008a), environmental and economic transformations in turn affect land management regimes and decision-makers. In particular, rural livelihoods across a wide cross-section of countries and regions have been affected by changing environmental/extractive regimes on the one hand (e.g., Bebbington et al. 2008), and political economic/structural transformations on the other (e.g., Hecht and Saatchi 2007; Kinsey 2002; Rudel 2002; Tanner 2003). Rural smallholding households are often the locus of development and conservation intervention (Rufino et al. 2008), in large part because their responses to variable biophysical and socioeconomic contexts drive resource

use, land management and productivity, and therefore future trajectories of local development and landscape change. Many other transformations accelerate the incorporation of rural smallholders into global economies, as both producers of goods and commodities, and as labor. As this intensified incorporation also occurs in Mexico's southern Yucatán region—a region long identified as an agricultural and development frontier—smallholders can be expected to adjust their in-place agricultural strategies. We thus ask the questions: How are households adjusting their agricultural strategies in this globalizing frontier? Is this adjustment unfolding uniformly or along different trajectories? And if the latter is the case, can we distinguish among households moving in different directions? Finally, how will these changes affect the conservation of forest cover in the region?

The southern Yucatán (SY) region has gone through a number of different waves of resource extraction (Klepeis 2004), linked in various ways to the livelihood strategies of individual households. In the latter half of the twentieth century, individuals and families arrived to the region from other states of Mexico, in search of livelihood opportunities. Most of these people eventually established homesteads within communal land management units known as *ejidos*, and built a life based on farming parcels of ejidal land. Livelihood activities were centered on agriculture, particularly *milpa* and its traditional, semi-subsistence cultivation of maize (Klepeis et al. 2004). Growing education and consumption opportunities, as well as growing lifestyle expectations, have driven a recently expanded household demand for cash income. Yet, farming households find that their cash income demand cannot be met through maize cultivation, particularly following Mexico's neoliberal shift in the 1990s (Echánove and Steffen 2003; Nadkami and Vedini 1996) and the accompanying structural adjustments in the agricultural sector (Foley 1995). Farmers have experimented with various cash crops, but their primary agricultural strategy has been the semi-subsistence cultivation of milpa followed by several years of fallow (Schmook this issue). Although the Mayan milpa traditionally refers to an intercrop of maize, beans, and squash, contemporary milpa cultivation in the southern Yucatán commonly entails the growing of these crops in rotation or simply the cultivation of maize under semi-subsistence conditions. Chili pepper became popular as a cash crop with many farmers, its regional cultivation peaking during the 1990s. Although the majority of farmers experimented over multiple years with chili, its cultivation in the SY carries a high risk of financial failure, due to vagaries of weather, pests, and a volatile market. This high risk has left many farmers either indebted or hesitant to pursue further chili cultivation (Keys 2005; Keys and Roy Chowdhury 2006). Temporary out-migration is increasingly significant in the region, with an explosion at the start of the twenty-first century in the percent of households with a family member in the United States or elsewhere in Mexico (Schmook and Radel 2008). The significance of migration flows in affecting land management has been detailed for the broader region (e.g., Carr 2008b). Households also rely heavily on income transfers from the Mexican state in the form of agricultural subsidies such as *PROCAMPO* (meant to cushion temporarily the impacts of structural adjustment), maintenance payments for conservation interventions (Roy Chowdhury and Turner 2006), or conditional-transfer poverty alleviation programs such as *OPORTUNIDADES* (Klepeis and Roy Chowdhury 2004). Local off-farm opportunities to earn cash income remain scant, despite official state efforts to promote and expand the tourism sector.

As a result of the structural and socioeconomic transformations underway in the SY, we hypothesize a transition in household livelihood strategies away from a primary reliance on milpa cultivation, supplemented by chili or the occasional other cash crop and by pasture cattle (See Busch and Geoghegan, this volume), to an increasingly diverse set of economic activities—both in and out of agriculture. This article examines evidence for a smallholder agricultural livelihood transition at the turn of the millennium and seeks to link this livelihood transition to decreased deforestation rates (Rueda, this issue) and evidence of an emerging forest transition observed through the analysis of remotely sensed imagery (e.g., Roy Chowdhury and Schneider 2004; Schmook et al. 2010; Vester et al. 2007). We draw from field-derived social surveys of smallholding rural households to identify the main agricultural livelihood strategies in the face of the social and environmental transformations in southern Mexico, and link them to their land use and cover impacts. Specifically, we investigate (1) any changes during the time period 1997–2003 in the proportion of households engaging in distinct strategies, (2) any significant sociodemographic differences among households following distinct livelihood strategies in the year 2003, (3) the main environmental impacts of those strategies (land use/cover impacts and agrochemical use in cultivation) in the year 2003, and (4) any changes during the 1997–2003 time period in the aforementioned environmental impacts of given strategies.

The results indicate that smallholder households are adjusting in diverse ways to changing structural and socioeconomic conditions. On the one hand, we find that an increasing number of households are withdrawing from agriculture and shifting into off-farm livelihood activities, often including wage labor in the United States. Newly emergent household strategies encompassing off-farm work are mirrored elsewhere in Mexico (de Janvry and Sadoulet 2001), as well as more broadly across Latin

America, leading to recent claims of an imminent Latin American forest transition based on out-migration and the abandonment of the more agriculturally marginal lands (Aide and Grau 2004; Hecht and Saatchi 2007). On the other hand, we find that a small but growing number of households are intensifying and/or commercializing agricultural production, focusing on various market-oriented agricultural activities, particularly cattle production (Busch and Geoghegan, this issue). This second group of households may also engage in out-migration, but this migration is not associated with a withdrawal from agriculture. Instead, these households engage extensively in agriculture, likely adjusting cultivation choices in response to labor constraints associated with migration (Busch and Geoghegan, this issue). These household livelihood adjustments impact regional land use/cover (Rueda, this issue; Roy Chowdhury and Turner 2006), with implications for ecological services such as carbon sequestration (see Geoghegan et al, this issue). Following a brief discussion of our methods, we present below the evidence for these diverging livelihood strategies, and explore the land changes likely to accompany them.

Methods

Surveys for the 2003 agricultural cycle were carried out over an 18-month period beginning in January 2004. One of the authors collected the survey data through interviews with 203 households in 14 different ejidos (communally owned farming settlements and lands) distributed across the SY region. The majority of households in the survey were selected for interview based on their inclusion in an initial 1997 SYPR survey,[1] which identified 188 households via a random sample in 11 ejidos. Other households were selected randomly to improve the geographic coverage of the data or to replace a number of households that became unavailable subsequent to 1997. The 14 ejidos with households included in the 2003 survey were broadly distributed with respect to their dates of establishment in the region, geographic location, biophysical (elevation, rainfall) gradients, total land area, and number of resident households. All surveyed households included a member holding formal ejidal rights (termed an *ejidatario*) within the ejido of residence. The research described in this article flows from these 1997 and 2003 surveys and thus stands as distinct from the anthropological research carried out by Gurri (this issue) with households in a different set of ejidos in the region. The two survey years involved no special environmental or socioeconomic shocks to the system and appear to be representative of the surrounding years. See the "Methods appendix" for additional survey details.

Interviews solicited information on various topics related to agricultural production and household dynamics, including data on out-migration and remittances and a range of other household income sources. In most cases, the interviewer spoke at length with both the male and female household heads independently. These conversations were based on a structured interview instrument, divided into two sections. The first section, usually carried out with the male household head, focused on questions of agricultural production, a male-dominated/controlled endeavor in most ejidos in the region. The second section, usually carried out with the female household head, focused on household demographics and livelihood activities more broadly pursued by all household members. In cases of the male head's absence (e.g. due to his temporary migration to the United States), the interviewer conducted both sections with the female head, often with an adult son present for agricultural production questions. Additional land use information collected included (1) areas under cultivation in maize, chili, and pasture, and (2) the use of chemical inputs to agricultural land use (for potential environmental impacts that extend beyond land cover). These land use data are examined with respect to varying livelihood strategies.

In order to analyze agricultural livelihood strategies, we divided surveyed households into eight groups (Table 1) based on their engagement or not in each of four dominant agricultural activities of the region: maize, chili, pasture, and cattle. We treat pasture and cattle as two distinct activities, as numerous households in the region establish pasture without cattle (see a brief discussion of this phenomenon later in the article). These groups range from no agricultural activity (some households might still raise the occasional chicken) to diversified participation in all four agricultural activities. We excluded three households from the analyses due to their cultivation of papaya, but not maize, chili, pasture, or cattle, resulting in an effective sample of 200 households for the year 2003. The excluded households were too few to constitute their own group, but did not logically fit into any of the other defined groups. In addition, a few households in the region practice agroforestry, maintaining plots within their land parcels or home gardens in which they combine agricultural and tree species in various configurations. These activities are often linked to local conservation/reforestation initiatives and subsidies, and may be viewed as a supplementary (rather than primary) livelihood strategy. Parcel allocations to agroforestry/reforestation are not examined in the surveys reported in this article, but have been detailed elsewhere

[1] The SYPR (or Southern Yucatán Peninsular Region) project is an interdisciplinary effort to understand land change in the SY region and began in 1997 (Turner, this issue).

Table 1 Eight household groups as defined by four primary agricultural activities

Group	Brief group description	Maize	Chili	Pasture	Cattle
1	No agricultural activities				
2	Maize only	✔			
3	Maize and chili	✔	✔		
4	Maize and pasture	(✔)		✔	
5	Maize, chili, and pasture	(✔)	✔	✔	
6	Maize, pasture, and cattle	✔		(✔)	✔
7	Maize, chili, pasture, and cattle	✔	✔	(✔)	✔
8	Cattle and pasture			✔	✔

(✔) A few households in Groups 4 and 5 did not cultivate maize in 2003. In 1997, 10 households with cattle in Groups 6 and 7 reported no pasture. See the group descriptions for further information

(e.g., Roy Chowdhury 2007; Roy Chowdhury and Turner 2006). For a few additional details on household inclusions in the eight groups, see the methods appendix below.

We analyzed the eight household groups in 2003 for a series of sociodemographic and land use/management variables, employing one-way ANOVAs in the case of continuous variables and Chi-square tests in the case of categorical variables. These 2003 cross-sectional comparisons examine the divergence of the eight household groups along different agricultural livelihood paths, in order to anticipate their potential landscape and environmental implications. Furthermore, we carried out comparisons (using one-way ANOVAs and cross-tabulations) between 1997 and 2003 to illuminate trends over time. Specifically, we examined changes in (1) size of membership in the eight defined household groups, and (2) areas (in hectares) under use by households in the groups for the primary agricultural activities of maize, chili, and pasture, as well as the number of cattle. The variables included in our analyses, along with their descriptive statistics are summarized in Table 2 below.

Results

Household agricultural livelihood groups and changes in membership, 1997–2003

The first group (Group 1) consists of households that did not farm actively in the year in question. Although some may have kept the occasional chicken, these households did not invest in animal husbandry/cattle production, and all their major livelihood activities occurred off-farm. In 1997, Group 1 consisted of a single household (0.5%), but by 2003 there were ten households (5%) not farming actively (see Table 3). In contrast, households in Group 2 cultivated maize, but did not engage in any of the other major agricultural activities prevalent in the SY region (chili, pasture, and cattle). This livelihood strategy (only growing maize) was adopted by the largest proportion of surveyed households in both 1997 and 2003, but exhibited a decrease over the time period (from 28 to 22% of households; $\chi^2 = 1.99$, $p < 0.10$). Furthermore, interviews conducted during the household surveys suggested that this group was more likely than any other group to have undertaken maize production in the context of the traditional milpa cultivation. Group 3 comprises households that farmed maize, but additionally allocated a portion of their land parcels to the cultivation of jalapeño chili, the region's main market crop. In 1997, combining across all strategy sets that include chili, roughly half of all households were cultivating chili (51% of surveyed households), with the vast majority (98% of surveyed households) also cultivating maize. The dual agricultural livelihood strategy of maize and chili had not been abandoned by SY farming households by 2003 (see Table 3); although not all households supplement maize cultivation with chili as a cash crop.

Group 4 summarizes 34 households whose livelihood portfolios combined maize cultivation with pasture on their land parcels, but without any cattle holdings. Pasture establishment and maintenance in the SY region may occur independently of cattle acquisition and production (Busch and Geoghegan, this issue; Klepeis and Vance 2003). Farmers who establish pasture will usually do so on former maize plots—in what can be considered as a milpa-pasture strategy. This household-level successional strategy is reflected in land change pathways at larger (e.g., community) scales elsewhere in Latin America, for instance, informing the "hollow frontier" thesis in Amazonia forest change (Casetti and Gauthier 1977; Rudel et al. 2002). This pasture establishment (and subsequent maintenance) is done in hopes of eventually obtaining cattle, and often with the support of government programs such as *Alianza para el Campo*. The maize-pasture strategy may entail clearing secondary vegetation encroaching on former milpa plots, and seeding appropriate grass species. From 1997 to 2003, Group 4 increased in proportionate size from 10 to 17% ($\chi^2 = 3.91$, $p < 0.05$).

Households in Group 5 had highly diversified agricultural landholdings, combining maize and chili with pasture, although without actual cattle holdings. This group did not increase in proportion over the 1997–2003 period. Households in Groups 4 and 5 invest labor into pasture establishment and maintenance in anticipation of cattle acquisitions; therefore, we consider them transitional (between those without and with cattle holdings). Whether any given household in Group 4 or 5 will succeed in acquiring cattle is uncertain, and contingent on sources of

Table 2 Variables included in the analyses (2003 only; 1997–2003) and descriptive statistics

2003 only variables	Description	2003 sample	
		Mean or percent (SD)	Min (Max)
Land endowment	Continuous variable; in hectares; ejidal land right and additional land purchased, rented, or borrowed	71 (42)	1 (260)
Household size	Continuous variable; in persons	5.2 (2.5)	1 (13)
Age of male household head	Continuous variable; in years	47 (14)	24 (80)
Education of male household head	Continuous variable; in years	3.5 (3.5)	0 (16)
Migration to US by male household head	Categorical variable; was the male head of household in the US or not	7.9%	–
Migration to US by any household member	Categorical variable; was any household member, including the male head, in the US or not	24%	–
Secondary vegetation	Continuous variable; in hectares; area of land under secondary vegetation	19 (21)	0 (216)
Maize intercropped with beans	Categorical variable; did the household plant maize intercropped with beans or not	49%	–
Maize chemical input use	Categorical variable; did the household employ chemical inputs in conjunction with maize or not	33%	–

2003 and 1997 comparison variables	Description	2003 sample		1997 sample	
		Mean (SD)	Min (Max)	Mean (SD)	Min (Max)
Primary vegetation	Continuous variable; in hectares; area of land under primary vegetation	35 (34)	0 (171)	35 (46)	0 (297)
Maize	Continuous variable; in hectares; area planted in maize	3.3 (3.6)	0 (28)	4.5 (4.0)	0 (30)
Chili	Continuous variable; in hectares; area planted in chili pepper	0.5 (0.8)	0 (4)	0.7 (1.2)	0 (9)
Pasture	Continuous variable; in hectares; area under pasture; for 1997, this variable is calculated from sketch maps of the household land holdings, as opposed to being reported by the survey respondent	9.9 (18)	0 (100)	8.6 (19.2)	0 (145)
Cattle	Continuous variable; in heads; number of cattle owned by the household	5.2 (16.4)	0 (120)	3.4 (11.1)	0 (91)

Table 3 Cross-tabulation of membership in the household groups in 1997 versus 2003

Group	Brief group description	1997		2003		χ^2
		Number of households ($n = 188$)	Percent of households	Number of households ($n = 200$)	Percent of households	
1	No agricultural activities	1	0.5	10	5.0	7.023***
2	Maize only	52	27.7	43	21.5	1.989*
3	Maize and chili	37	19.7	35	17.5	0.305
4	Maize and pasture	19	10.1	34	17.0	3.905**
5	Maize, chili, pasture	31	16.5	31	15.5	0.071
6	Maize, pasture, cattle	19	10.1	23	11.5	0.195
7	Maize, chili, cattle, pasture	27	14.4	15	7.5	4.727**
8	Cattle and pasture	2	1.1	9	4.5	4.154**

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

cash income, especially those that allow for an accumulation of savings. As Busch and Geoghegan discuss in this same issue, cattle production entails considerable fixed costs for infrastructural development of fencing and water supplies.

Households that actually own cattle differed from one another in their investment in other agricultural activities. For instance, Group 6 consists of households that had one or more heads of cattle (usually on their established pasture lands), and additionally cultivated maize. Households in Group 7, on the other hand, combined cattle-pasture holdings with maize cultivation as well as commercial chili farming. This group of households thus follows the most diversified agricultural livelihood strategy. Interestingly, the size of Group 7 decreased by half from 1997 to 2003 (from 14 to 8%; $\chi^2 = 4.727$, $p < 0.05$); while Group 6 remained stable. The most unusual strategy, that of investing wholly in cattle and pasture to the exclusion of all other farming activities, was adopted by a small number of households in Group 8. These households maintained pastures through seeding and periodic burns, and may occasionally supplement cattle feed through purchased inputs. From 1997 to 2003, the proportion of households in Group 8 grew from 1 to 5% ($\chi^2 = 4.15$, $p < 0.05$).

Differences among groups in sociodemographic factors, including land endowment and migration, 2003

In order to further understand households' selection of livelihood strategies, we compared the eight household groups in 2003 to identify any group differences in several key variables. Research on determinants of rural livelihood and land use strategies has identified numerous demographic and socioeconomic factors as critical drivers of household choices, including household demographic factors such as age, fertility, mortality, life cycles and migration (de Sherbinin et al. 2008), assets and endowments (Babulo et al. 2008), land tenure (Luoga et al. 2005; Carr 2008a), education (Iiyama et al. 2007) and other variables. Informed by this work and drawing on prior research in the study area, we focus on the following factors as they affect household livelihood choices: land area endowment, household size, age of male head of household, education level of male head of household, US migration of male head of household, and US migration of any member of the household (see Table 4 below). Our purpose was to identify any differences that might help explain different household choices in agricultural livelihood strategy, as defined by the eight household groups.

Individual ejidos differ in their size of customary land allocation to their ejidatarios. In addition, households within ejidos may hold variable land rights based on the ejido's history of allotment or on the household's holding of multiple rights. For example, both the man and the woman might hold land rights (this is relatively unusual) or both a father and a son might hold land rights (this is more common). Furthermore, ejidal households acquire additional land through purchasing, renting, or borrowing. We found few statistically significant differences among the eight household groups with respect to the area (in hectares) of their land endowment; although Group 6, one of the more diversified household groups, had a higher mean land endowment (see Table 4 below). We found few significant group-wise differences in mean age or years of education of the male household head (see Table 4); although Group 8 had a slightly younger male head than Group 5 ($p < 0.05$). Group 1 tended to have better educated male heads; while Group 3 tended to have less-educated male heads. Households in chili-cultivating groups (3 and 5) tended to be slightly larger in size, and neither educational level nor age appears to play a definitive role in their chosen agricultural strategy.

Table 4 Sociodemographics and land endowment: Comparisons of 2003 group means (percents for categorical variables; standard deviations in parentheses)

Group	Land endowment (ha)	Household size	Male household head: age	Male household head: education	Male household head in the US	Any household member in the US
1: No agricultural activities	53 (40)	4.1 (2.1)	45 (15)	6 (5)	20%	50%
2: Maize only	62 (46)	4.7 (2.3)	49 (15)	3 (4)	7%	14%
3: Maize/chili	66 (38)	6.0 (2.8)	47 (14)	2 (3)	0%	14%
4: Maize/pasture	72 (35)	4.9 (2.2)	47 (15)	4 (4)	15%	29%
5: Maize/chili/pasture	64 (27)	6.1 (2.6)	49 (12)	3 (3)	7%	32%
6: Maize/pasture/cattle	103 (54)	4.8 (2.3)	47 (12)	5 (5)	0%	22%
7: Maize/chili/pasture/cattle	82 (40)	5.4 (2.5)	46 (15)	4 (3)	0%	7%
8: Cattle/pasture	62 (33)	5.1 (2.1)	40 (11)	3 (2)	33%	56%
Reference group 1	6 ($F = 6.87$)**	3 ($F = 4.28$)**	–	3 ($F = 6.62$)**	3 ($\chi^2 = 7.33$)***	2 ($\chi^2 = 6.41$)**
	7 ($F = 3.09$)*	5 ($F = 5.23$)**			6 ($\chi^2 = 4.90$)**	3 ($\chi^2 = 5.74$)**
					7 ($\chi^2 = 3.26$)*	7 ($\chi^2 = 6.18$)**
Reference group 2	6 ($F = 10.64$)***	3 ($F = 5.62$)**	–	–	8 ($\chi^2 = 5.07$)**	4 ($\chi^2 = 2.76$)*
		5 ($F = 6.65$)**				5 ($\chi^2 = 3.56$)*
						8 ($\chi^2 = 7.72$)***
Reference group 3	6 ($F = 9.54$)***	1, 2[a]	–	4 ($F = 4.96$)**	4 ($\chi^2 = 5.55$)**	5 ($\chi^2 = 3.02$)*
				6 ($F = 4.60$)**	8 ($\chi^2 = 12.52$)***	8 ($\chi^2 = 6.94$)***
				1[a]	1[a]	1[a]
Reference group 4	6 ($F = 6.87$)**	5 ($F = 3.09$)*	–	3[a]	6 ($\chi^2 = 3.71$)*	7 ($\chi^2 = 3.09$)*
					3[a]	2[a]
Reference group 5	6 ($F = 12.17$)***	6 ($F = 4.10$)**	8 ($F = 4.16$)**	–	8 ($\chi^2 = 4.61$)**	7 ($\chi^2 = 3.64$)*
	7 ($F = 3.15$)*	1, 2, 4[a]				2, 3[a]
Reference group 6	8 ($F = 4.53$)**	5[a]	–	3[a]	8 ($F = 8.46$)***	8 ($\chi^2 = 3.44$)*
	1, 2, 3, 4, 5[a]				1, 4[a]	
Reference group 7	1, 5[a]	–	–	–	8 ($\chi^2 = 5.71$)**	8 ($\chi^2 = 7.17$)***
					1[a]	1, 4, 5[a]
Reference group 8	6[a]	–	5[a]	–	2, 3, 5, 6, 7[a]	2, 3, 6, 7[a]

Note: In the lower half of the table, each cell for a reference household group (row) reports which groups were found to have significantly different means as compared to the reference group in that row, noting the corresponding F-statistic or χ^2 value

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

[a] See details in earlier relevant cell (e.g. for Reference Group 6 compared to Group 1, see Reference Group 1 compared to Group 6)

The decision to migrate, either by the household head or by a different household member (usually an adult son who has not formed his own separate household yet), occurs in conjunction with agricultural strategies. We found the highest rates of temporary migration among Groups 1 and 8—with households engaging in either no agricultural activities or in cattle-pasture production only (see Table 4). Choice of household agricultural activities is likely primarily an effect (as opposed to a cause) of a labor out-migration decision, but our findings can only indicate an association and not causality. We found relatively high rates of migration among households that established or maintained pasture (either with or without cattle). The exception is Group 7 (maize, chili, pasture, cattle), with relatively low rates of temporary out-migration.

Differences among groups in land use/management, 2003

As households diversify from a common, shared semi-subsistence cultivation of maize to include chili, pasture, and cattle, their allocation of parcel land to various uses/covers (primary and secondary vegetation, maize, chili, and pasture) is likely to change. Thus, differences among the eight groups imply land use variability and environmental change across the SY. Table 5 below compares land use/management across the eight household groups in 2003.

The three chili producing groups (Groups 3, 5 and 7) cultivated approximately one hectare of chili (mean for all three groups), although numerous households among the three groups cultivated two or more hectares. There were

Table 5 Land use and management: Comparisons of 2003 group means (percents for categorical variables; standard deviations in parentheses)

Group	Primary Vegetation (ha)	Secondary Vegetation (ha)	Maize (ha)	Chili (ha)	Pasture (ha)	Head of cattle	Maize intercropped with beans	Maize chemical inputs
1: No agricultural activities	38 (37)	15 (20)	NA	NA	NA	NA	NA	NA
2: Maize only	36 (36)	19 (21)	3.0 (2.9)	NA	NA	NA	56%	30%
3: Maize/chili	38 (37)	20 (14)	3.4 (2.3)	1.3 (0.8)	NA	NA	57%	14%
4: Maize/pasture	41 (37)	14 (11)	2.9 (1.4)	NA	11.2 (11.4)	NA	45%	28%
5: Maize/chili/pasture	30 (30)	19 (9)	4.3 (2.1)	1.2 (0.8)	7.1 (6.8)	NA	67%	37%
6: Maize/pasture/cattle	30 (31)	30 (46)	5.9 (5.9)	NA	31.4 (20.1)	22 (25)	30%	61%
7: Maize/chili/pasture/cattle	30 (23)	21 (11)	4.6 (6.6)	1.1 (0.7)	22.4 (27)	16 (25)	20%	47%
8: Cattle/pasture	22 (34)	7 (10)	NA	NA	31.4 (20.1)	41 (35)	NA	NA
Reference group 1	–	–	NA	NA	NA	NA	NA	NA
Reference group 2	–	–	5 ($F = 4.48$)**	NA	NA	NA	6 ($\chi^2 = 3.87$)**	3 ($\chi^2 = 2.76$)*
			6 ($F = 7.31$)***				7 ($\chi^2 = 5.73$)**	6 ($\chi^2 = 5.82$)**
Reference group 3	–	8 ($F = 6.37$)**	6 ($F = 5.10$)**	–	NA	NA	6 ($\chi^2 = 3.98$)**	5 ($\chi^2 = 4.36$)**
							7 ($\chi^2 = 5.83$)**	6 ($\chi^2 = 13.67$)***
								7 ($\chi^2 = 6.04$)**
Reference group 4	–	6 ($F = 6.87$)**	5 ($F = 8.95$)***	NA	5 ($F = 2.98$)*	NA	5 ($\chi^2 = 2.85$)*	6 ($\chi^2 = 5.82$)**
		7 ($F = 3.77$)*	6 ($F = 7.18$)***		6 ($F = 16.07$)***			
		8 ($F = 3.40$)*			7 ($F = 4.12$)**			
					8 ($F = 15.64$)***			
Reference group 5	–	8 ($F = 12.31$)***	4[a]	–	6 ($F = 23.81$)***	NA	6 ($\chi^2 = 6.84$)***	6 ($\chi^2 = 3.06$)*
					7 ($F = 8.91$)***		7 ($\chi^2 = 8.72$)***	3[a]
					8 ($F = 33.49$)***		4[a]	
					4[a]			
Reference group 6	–	4[a]	2, 3, 4[a]	NA	4, 5[a]	–	2, 3, 5[a]	2, 3, 4, 5[a]
Reference group 7	–	8 ($F = 9.59$)***	–	–	4, 5[a]	8 ($F = 3.95$)*	2, 3, 5[a]	3[a]
		4[a]						
Reference group 8	–	3, 4, 5, 7[a]	NA	NA	4, 5[a]	7[a]	NA	NA

Note: In the lower half of the table, each cell for a reference household group (row) reports which groups were found to have significantly different means as compared to the reference group in that row, noting the corresponding F-statistic or χ^2 value

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

[a] See details in earlier relevant cell (e.g. for Reference Group 6 compared to Group 4, see Reference Group 4 compared to Group 6)

no significant differences among the groups in chili area. According to the interviewees, chili areal allocation reflects a desire to cultivate chili using predominantly family labor—farming only one to two hectares of chili reduces the need to hire extra-household labor, typically required during harvests. Interviews further revealed the importance of household abilities to mobilize capital needed for inputs.

The four groups maintaining pasture (Groups 4, 5, 6 and 7) exhibited some significant differences in pasture areas (Table 5). Overall, households that actually had cattle holdings also maintained larger areas under pasture than households that planted pastures but did not own cattle. For example, Group 4 (maize and pasture) has a mean of approximately 11 hectares under pasture; while Group 6 (maize, pasture, and cattle) has a mean of 31 hectares under pasture ($F = 16.07$, $p < 0.01$). Pooling the four pasture-maintaining household groups into two sets based on the presence or absence of actual cattle holdings revealed significant differences in mean pasture extents (30 ha for households with cattle and only 9 ha for those without; $F = 32.13$, $p < 0.001$). Not surprisingly, households that specialize exclusively in pasture and cattle (Group 8) owned significantly more heads of cattle (mean of 41) compared to Group 7 households combining maize, chili, pasture, and cattle (mean of 16 cattle) ($F = 3.95$, $p < 0.1$).

Households with more diversified agricultural portfolios (Groups 5 and 6) tend to cultivate more maize (Table 5). This was not true for the most diversified group (Group 7), a finding that could also reflect the high variance in area under maize observed within this group. Additional survey questions captured information on differing household practices in the cultivation of maize, in particular, recording whether maize was planted by itself, or intercropped with beans. The intercropping of maize and beans is a good indicator for the cultivation of maize as traditional milpa (as opposed to as a monocrop). The more diversified groups were less likely to have intercropped maize with beans (Table 5). Chemical inputs (herbicides, insecticides, and commercial chemical fertilizers) are not ubiquitous in maize production, and when they are used, may have important environmental impacts. We found that only 30% of all households in Group 2 (maize only) and only 14% in Group 3 (maize and chili) used chemical inputs in maize cultivation in 2003, whereas 61% of households in Group 6 (maize, pasture, and cattle) and 47% of households in Group 7 (maize, chili, pasture, cattle) used chemical inputs for their maize cultivation (Table 5).

The household groups did not vary greatly in their areas under primary vegetation (forests), but exhibited significant differences in areas under secondary (successional) vegetation. Households solely producing pasture and cattle (Group 8) maintained smaller areas on average in secondary vegetation. Group 6 (maize, pasture, and cattle) had the largest mean area under secondary vegetation; however, they also had the highest land endowment.

Changes in land use (1997–2003) across the eight household groups

In order to fully understand the implications of household agricultural activities for regional environmental change, it is important to clarify whether or not the area of cultivation (or number of cattle) for each of the primary agricultural activities is changing over time *within each of the eight household groups*. Comparing the relative size of each group (in terms of the proportion of households) for 1997 and 2003, as well as the mean hectares under various land uses (or number of cattle) for 1997 and 2003, is necessary to identify trends in landscape impacts. For example, has the mean area under chili cultivation changed over the six-year period for any of the household groups defined by their cultivation of chili?

As the findings in Table 6 illustrate, we identified few statistically significant differences in mean areas under various land uses for 1997 versus 2003. Land area under primary vegetation remained relatively stable, with one exception. For Group 5 (maize, chili, and pasture), the mean area of land under primary vegetation decreased (from 47 to 30 ha; $F = 2.92$, $p < 0.1$). We were not able to compare areas of secondary vegetation, as these data were not collected in the 1997 survey. Mean areas under maize, chili, and pasture also remained stable, as did the mean number of cattle, within each of the respective groups. Again, we found a single exception: For Group 3 (households cultivating maize and chili only), the mean area planted in maize dropped from roughly five hectares to three and a half ($F = 4.10$, $p = 0.05$).

Discussion

An emerging divergence in household livelihood strategies with respect to agriculture

Changes (1997–2003) in agricultural livelihoods for the sampled SY households were modest, yet statistically significant and meaningful. A small but increasing proportion of households in the region engaged in no agricultural activities, or in the commercial production of cattle. For a group of households, the dual maize-chili strategy has persisted with no evidence of change, as have the more diversified strategies of maize-chili-pasture and maize-pasture-cattle. However, households engaged in primarily semi-subsistence maize production are relatively less abundant. Remarkably, the proportion of households engaged in the most highly diversified set of agricultural

Table 6 Groupwise comparison of land-use means (in hectares), 1997 and 2003

	Group 1 No agricultural activities	Group 2 Maize only	Group 3 Maize and chili	Group 4 Maize and pasture	Group 5 Maize, chili, pasture	Group 6 Maize, pasture, and cattle	Group 7 Maize, chili, pasture, cattle	Group 8 Cattle and pasture
Primary vegetation 1997	100	30.6	32.5	35.6	46.8	29.2	37.7	5.8
	SD nd	SD 39.4	SD 41.9	SD 32.9	SD 47.4	SD 37.7	SD 70.5	SD 6.0
Primary vegetation 2003	37.7	35.6	37.9	40.9	29.7	29.0	30.5	21.8
	SD 37.0	SD 36.2	SD 37.1	SD 36.8	SD 29.2	SD 30.6	SD 23.3	SD 29.8
	$F = 2.59$	$F = 0.41$	$F = 0.33$	$F = 0.28$	$F = 2.92$	$F = 0.00$	$F = 0.15$	$F = 0.53$
	$p = 0.14$	$p = 0.52$	$p = 0.57$	$p = 0.60$	$p = 0.09$*	$p = 0.99$	$p = 0.70$	$p = 0.48$
Maize 1997	NA	3.3	5.1	3.3	5.6	5.6	5.4	NA
		SD 2.0	SD 4.3	SD 1.8	SD 4.8	SD 6.4	SD 4.1	
Maize 2003	NA	3.0	3.4	2.9	4.3	5.9	4.6	NA
		SD 2.9	SD 2.3	SD 1.4	SD 2.2	SD 5.9	SD 6.6	
	NA	$F = 0.33$	$F = 4.10$	$F = 0.98$	$F = 1.89$	$F = 0.03$	$F = 0.21$	NA
		$p = 0.56$	$p = 0.05$*	$p = 0.33$	$p = 0.17$	$p = 0.86$	$p = 0.65$	
Chili 1997	NA	NA	1.1	NA	1.7	NA	1.3	NA
			SD 0.9		SD 2.0		SD 0.9	
Chili 2003	NA	NA	1.3	NA	1.2	NA	1.1	NA
			SD 0.8		SD 0.8		SD 0.7	
	NA	NA	$F = 1.47$	NA	$F = 1.44$	NA	$F = 0.55$	NA
			$p = 0.23$		$p = 0.24$		$p = 0.46$	
Pasture 1997	NA	NA	NA	10.2	12.8	19.3	22.4	28.0
				SD 12.7	SD 22.0	SD 38.2	SD 20.9	SD 2.8
Pasture 2003	NA	NA	NA	11.2	7.1	33.8	22.4	31.4
				SD 11.4	SD 6.9	SD 29.4	SD 26.9	SD 20.2
	NA	NA	NA	$F = 0.08$	$F = 1.85$	$F = 1.85$	$F = 0.00$	$F = 0.05$
				$p = 0.77$	$p = 0.18$	$p = 0.18$	$p = 0.99$	$p = 0.82$
Cattle 1997	NA	NA	NA	NA	NA	15.8	11.1	18.0
						SD 27.7	SD 10.2	SD 2.8
Cattle 2003	NA	NA	NA	NA	NA	21.8	15.5	40.6
						SD 25.5	SD 25.3	SD 34.8
	NA	NA	NA	NA	NA	$F = 0.53$	$F = 0.66$	$F = 0.77$
						$p = 0.47$	$p = 0.42$	$p = 0.41$

nd no data, as Group 1 had only one household in 1997

* $p < 0.1$

strategies (Group 7) also dropped by half—perhaps as households dropped their chili component (linked to the boom-bust market). Our results support the hypothesis of transitioning household agricultural strategies (although without as dramatic a change as anticipated for the 1997–2003 period), and we do observe an emerging divergence during the 1997–2003 period. An increasing number of households moved out of agriculture. Another set of households diversified, intensified (e.g. with chemical inputs), and/or commercialized their agricultural production.

Yet, no overarching/dominant pattern emerges from our data to elucidate household socioeconomic differences along these diverging paths, indicating the complexity of household strategic choices, at least for the broad categories analyzed in this article. Although one of the more diversified household groups (Group 6) had a higher mean land endowment in 2003, results for land endowment as a driver for household livelihood choice are unclear. In a distinct study of land use portfolios conducted in two ejidos in the SY region, Roy Chowdhury and Turner (2006) found that when controlling for other sociodemographic factors, the size of land entitlements did not significantly drive areas allocated to milpa, chili, or pasture in household parcels. Results here suggest that land endowment *may* play some role in the adoption of those more diversified

agricultural strategies including cattle; however, the mediating effects of other variables such as labor strategies and access to subsidies and social/economic capital merit deeper scrutiny. It is important to note here that households residing within the ejidos but without any ejidal rights (*pobladores*) were not included within the research presented in this article. One might expect these poblador households to condition their livelihood strategies heavily on land access, given their lack of rights to a defined parcel of ejidal lands. Education and age may play small contributing roles in the transition in household livelihood strategies. Educational levels for male heads of households were low in 2003, but are rapidly changing. There is some indication that more educated and younger households are leading the livelihood transition, diverging both out of agriculture and into commercially oriented activities such as cattle ranching. As a new generation leaves school (with substantially more education than their parents) and establishes independent households, a significant impact on livelihood strategy may materialize.

The emergence and expansion of temporary labor migration is more strongly associated with changes in agricultural livelihood strategies than other examined household characteristics. In 2003, migration was associated with both paths of the livelihood divergence—out of agriculture or into a more commercially oriented production centered on cattle. Migration was not, however, associated with more intensified chili cultivation. The cultivation of chili is relatively incompatible with the migration of the male household head. In earlier research in the region, we found that many households were substituting temporary out-migration for chili cultivation (Radel and Schmook 2008). We discuss the relation between temporary out-migration and household land use at length elsewhere: For example, in other research based upon the same 2003 survey, we found that households engaging in labor migration to the United States were more likely to be expanding land under pasture and less likely to be cultivating maize and chili (Schmook and Radel 2008).

Implications for regional environmental change

In order to understand the implications of livelihood strategies for regional environmental change, we needed to understand both (1) differences in the land use and management impacts among distinct household groups (agricultural strategies); and (2) land use transformations over time for any given strategy or group. On the latter— land use transformations over time—we found little change for most household groups. An important exception is that the set of households diversified in maize, chili, and pasture reduced their areas under forest cover—a trend that, if maintained, could result in potentially important implications for forest cover and connectivity, as well as carbon sequestration at the regional scale (e.g., Geoghegan et al., this issue). On the former, however, we did find evidence of change with important implications for future environmental and landscape change in the region.

Maize production and its environmental impacts are changing in the SY. Use of chemical pesticides and fertilizers for maize cultivation indicates a more commercial orientation and an intensified production strategy. An intensive (vs. extensive) maize production strategy is also consistent with the significant reduction (1997–2003) in maize area planted by households specifically cultivating only maize and chili. A transition from semi-subsistence maize cultivation to a more intensified maize production on a larger area as part of a diversified agricultural strategy across other household groups has environmental implications: Increased chemical usage raises concerns over chemical runoff, pesticide resistance, and human health consequences, with linkages as well to biodiversity conservation.

Chili production was already relatively intensive and reliant on chemical inputs, but production did not expand during the period in question. Other research in the region has highlighted the importance of financial constraints to chili cultivation. For instance, parcel areas allocated to chili have been found to be significantly determined by payments through government poverty alleviation programs and/or agricultural and conservation land use subsidies (Keys and Roy Chowdhury 2006; Roy Chowdhury and Turner 2006). Our results here indicate that while a household's decision to farm chili was obviously reflected in its chili holdings, further agricultural diversification did not alter the area under chili cultivation. This finding reflects the fact that household livelihood portfolios in this region include land uses that supplement rather than supplant each other as the region's farmers experiment with various production strategies in meeting subsistence and commercial objectives (e.g., Roy Chowdhury and Turner 2006). If more households choose to not include chili in their agricultural strategy or withdraw from agriculture altogether, area under chili in the region will drop. None of the household groups engaged in chili cultivation increased in size from 1997 to 2003, and one group even decreased. This is unsurprising: The high risks of chili cultivation and low farm gate prices in recent years have resulted in widespread disillusionment in the region with chili as a livelihood activity (Radel and Schmook 2008). The decreasing proportion of households planting chili was not offset by an expansion of cultivated hectares by those households continuing to farm it. Although a significant proportion of households still cultivated chili in 2003, with associated environmental and land use impacts, the regional production of chili appears to have been on the wane.

Overall, chili and maize cultivation are not likely to increase across the region, unless market prices increase. Although this occurred for maize briefly during the world food price crisis of 2007–2008, longer-term conditions have not changed. Area under pasture, on the other hand, appears to be on the increase, especially as households transition to obtaining and/or expanding cattle. Many of these changes can be linked to reduced in-place labor requirements of pasture/cattle (Busch and Geoghegan, this issue) in conjunction with increasing temporary labor out-migration (Radel and Schmook 2008; Schmook and Radel 2008).

Conclusion

Although the changes in the proportionate sizes of the eight household groups, from 1997 to 2003, have been relatively minor, some early trends are emerging as important for regional environmental/land change. The most important of these trends is the emerging agricultural livelihood transition with a divergence of households along two separate paths. One set of households is withdrawing from agro-pastoral land uses and livelihoods. A separate set of households continues to diversify and/or intensify agricultural activities by mixing maize, chili, and cattle production with an increasingly commercial orientation. For the most part, areas cultivated in maize and chili remain unchanged for those households continuing to cultivate these crops. However, a small but growing number of households cultivated neither maize nor chili in 2003, withdrawing from agricultural production altogether or deepening production of cattle as an agricultural specialization. Furthermore, if temporary labor out-migration continues to expand in the SY region, we can anticipate a further divergence in household livelihood strategies, with accompanying environmental change. Many households do continue to focus livelihood activities on semi-subsistence maize cultivation much as did the majority of households in the region just a few short decades ago. But although semi-subsistence maize producing smallholders maintain a significant presence, this group is diminishing and now represents the past of the SY. As smallholding rural households adjust agricultural strategies to the household's intensified incorporation into global economies, we are observing two significantly diverging paths of adjustment with seemingly contradictory potential land cover outcomes—the recovery of forests and the expansion of pasture for cattle. Thus, it is possible for us to observe two characteristics of the modern "hollow frontier" simultaneously—peasant agriculture giving way to ranching and a growing withdrawal of smallholders from agricultural production—as well as to observe a forest transition in the broader sense put forth by scholars (Turner 2009; Hecht and Saatchi 2007; Rudel et al. 2005). As both emerging household adjustment paths are responses to structural adjustments in the agricultural sector and are linked to the out-migration of labor, the SY case points to the possibility of simultaneous and contradictory land change outcomes as smallholders adapt their agricultural livelihood strategies in different ways to an intensified incorporation into global economies, perhaps selecting from perceived available options.

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Methods appendix

A few additional notes are helpful for a fuller understanding of our research methods:

Additional survey details

For additional detail on the 1997 survey, see Turner et al. (2004). The 2003 survey was part of a joint survey implemented in collaboration with Busch (Busch and Geoghegan, this issue), with the addition of one more ejido in the southern region. Due to the unavailability of a subset of households (45) from the 1997 survey, the 2003 survey added a set of replacement households (26) from the same ejidos. Households became unavailable either due to an unwillingness to participate in the second survey or due to a failure to persist in the ejido (either through death or through relocation within or out of the region). The 2003 survey also included 34 new households randomly selected from three additional ejidos, which were in turn randomly selected to represent better a group of newer and smaller ejidos in the southern reaches of the SY region.

Comparison with research by Gurri (this issue)

In addition to drawing on data from different sets of surveys and interviews, our research can be distinguished from that of Gurri by its different methods and an approach that takes the potential dynamism within sets of livelihood strategies as the point of departure. Gurri's research points to the roles played by culture and family history (prior to arrival in the region) in the selection of

livelihood strategies. Together, the two articles provide differing but complementary windows into understanding the changing human–environment relationship in the SY.

Division of households into the eight groups

As described in the methods section of the main article body, we divided surveyed households into eight groups based on their engagement in maize, chili, pasture, and cattle production. We determined how to define the groups based on the four main agricultural activities in the region, in a manner that could indicate different degrees of diversification among these activities. Knowledge of these four main activities comes from both the survey data itself and years of experience working in the region. We did not include agricultural activities that were rarely employed within the region, had no significant land use/land cover change implications, and/or were employed so widely as to not differentiate households (such as subsistence chicken raising). In addition, we included a few households in groups even in the absence of group-defining activities, if they did not otherwise fit another group and we also judged them to be a good group fit. These exceptions are detailed here:

Group 4 (maize and pasture). Five households of the 34 in Group 4 did not cultivate maize in 2003. We included these five households in this group due to the high likelihood that these households cultivated maize in a previous year and would cultivate maize again in the near future.

Group 5 (m*aize, chili, and pasture).* We included one household in Group 5 that did not cultivate maize in 2003 and only had chili and pasture. We included this household in Group 5 under the assumption of the milpa-pasture strategy.

Group 6 (maize, pasture, and cattle) and Group 7 (maize, chili, pasture, and cattle). In 1997, ten households in Groups 6 and 7 owned cattle, but reported no pasture lands; however, in 2003 all households reporting cattle also reported pasture lands.

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