Land Use Change in Altamira Settlement Area, Pará, Brazil:
Patterns Associated with Property Owner Migration or Ownership Change

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The large-scale clearing of forests for the planting of crops and pasture for cattle is the prime driver of environmental change in the Brazilian Amazon and elsewhere in the world. The resulting local changes in soils, land cover, the carbon budget, and trace gas fluxes have local, regional and global consequences. We have already begun to see local changes in precipitation patterns, with land clearing associated with less frequent but heavier rains (increasing runoff and erosion), and temperatures. These then impact the available moisture in air currents progressing across the continent, leading to drier conditions in the highly productive agricultural regions in the Southeast of Brazil. Changes in the carbon budget in the Amazon, increasing the amount of carbon released into the atmosphere relative to the amount taken out of the atmosphere, are important contributors to the global carbon imbalance associated with global climate change.

At a regional scale, we can understand land use change and associated climate change as anthropogenic and associated with the entry of large human populations into the previously sparsely populated Amazon. However, land use decisions are not made at a regional scale. They are made by individual property owners on a year-to-year basis. Therefore, we must understand the behavior of such landowners in relation to their land in order to understand both the human drivers of land use change and the policies we can implement to encourage more sustainable use at that level.

It is this question of household behavior which we address in this paper. In particular, we provide an empirical assessment of the role of landowner migration and property turnover (sale to a new owner) in land use change. Both migration and property turnover play prominently in the discussion of anthropogenic land change in the Amazon. In-migrants from elsewhere in Brazil are argued to come in to the frontier, clear land for slash and burn agriculture, and then move on to a new frontier when the land is exhausted and non-productive under the slash and burn management system. Similarly, the traditional story of frontier development suggests that the land is then purchased by large owners who intend to place all of a large area in cattle production (or mechanized row crop agriculture).

Thus, migration and sale are both seen to be associated with clearing of forest and secondary growth, and conversion of land to pasture (and sometimes to row crops).

This literature is largely independent of the literature focusing on the actions of smallholder farmers in the region. We review this literature, which has ignored the importance of migration and property sale, in the next section. The approaches taken in this literature are mostly deterministic, suggesting that land use is primarily determined by either household demography, biophysical characteristics of a property, or location / accessibility. Migration therefore enters into these models only as a change in household demography, or as unimportant because it does not change the other characteristics of the property. Our results suggest that these models might indeed be correct, that the migration of an owner or sale of a property has little relation with land use change while the migration of an individual reflects a previous investment in other properties or in the city.

Household Land Use Decision-Making

The dominant model of household land use decision-making combines the Chayanovian household economy approach with a modern household production model (Aldrich et al. 2006; Caldas et al. 2007; Walker 2003). The Chayanovian model is based on subsistence production, arguing that the area of land used by farming families depends on the needs of the family and their available labor, both of which are determined by household demographic composition (Chayanov 1966; McCracken et al. 2002; Walker and Homma 1996). Children and elderly members increase the consumption needs without increasing the available labor for production, while adult women and primarily adult men increase the productive capacity of the family. The model assumes a scarcity of labor and a surplus of land, a situation which characterizes the early stages of frontier settlement. It assumes no functioning labor market and no outlet for the sale of agricultural products. This model has been combined with a household production model (from modern development economics) which accounts for the presence of markets for the sale of products, leading to production constrained only by the available labor in the household and not by the needs of the household. However, this model does not relax the assumption of an absent labor market (and land market, though this is less essential).

Recent empirical and theoretical work on household demography and land use change in the Amazon has taken account of the unrealistic nature of many of the assumptions of these stylized models of household behavior, as well as noting the lack of explanatory power of the models (Aldrich et al. 2006; Caldas et al. 2007; VanWey et al. 2007). In particular, work by Caldas and colleagues modifies the household production model to account for the development of labor and land markets over the development of the frontier, as well as empirically modeling the switch from subsistence to market production (Caldas et al. 2007). This work shows that household production becomes more oriented to the market over time, and incorporates the Von Thünen bid-rent model to suggest the particular form of production taken. Similarly, work by VanWey and colleagues argues for the development of social and quasi-economic institutions as the frontier develops (VanWey, D'Antona and Brondizio 2006; VanWey et al. 2007). They suggest that household production decisions are strategic, aimed at increasing income and reducing risk, but are constrained by biophysical characteristics of properties and by information contained in social networks. Specifically, individual settlers in the early years of the frontier focus on meeting subsistence needs and experimenting with a variety of economically productive activities. As the frontier develops, the information contained in informal (family, friend) and formal (production cooperatives, agricultural extension) social networks grows and settlers can choose the most biophysically appropriate land use for a property within the choice set dictated by social norms.

This research comes on the heels of a number of empirical tests of the Chayanovian household model, showing that household demography rarely, if ever, is significantly related to land use at the property level. Both literature reviews covering small case studies with non-representative samples and empirical tests using data collected for this purpose show that household demographic composition is only loosely related to land use and is not related in the theoretically expected way (Perz, Walker and

Caldas 2006; VanWey, D'Antona and Brondizio 2006; VanWey et al. 2007;Walker et al. 2002). The only measure that is consistently related to household land use decisions in new frontiers is the time since occupation of the property, and this is only related to land use in young frontiers. VanWey et al. (2007) use this evidence to argue for the importance of social learning and institutional development to prevent extensive experimentation (and therefore deforestation and conversion from one crop to another) by settler households.

These models stand in contrast to models that posit environmental (or locational) determinism. Many models of land use change in the Amazon and elsewhere focus on the importance of the biophysical constraints on the productive capacity of land. In particular, there is variation across the region in soil fertility, water availability, and topography. Past research shows that the variation in land use change across the Amazon as a whole is by and large explained by macro level biophysical differences. Water availability limits the types of crops that can be grown (in the absence of widespread irrigation), and limits the viability of cattle ranching. Steep or rolling topography, which characterizes much of the Amazon, lowers the economic returns to mechanized agriculture (or makes it completely impossible). Property scale research has shown that the quality of soils is important in explaining whether a property is primarily pasture or primarily perennial production in our study area (Moran et al. 2002). Such models implicitly assume that humans are rational income maximizers, and that they are operating with complete information; they can ascertain the most appropriate land use given biophysical and technological constraints, and they will choose it.

Similarly, models based in Von Thünen's agricultural economics argue for the primacy of access to markets (and transportation costs) in determining the optimal land use when production is for sale (Walker expansion). These models argue that land closer to cities will be used for highly perishable and expensive crops (tomatoes, fruits, etc.). Land that is farther from the city (the market) will be used for lower value but less perishable crops (melons, potatoes, cattle, etc.) while land that is beyond a certain distance will not be used for commercial agriculture. If this is the case, we would expect to see only subsistence agriculture in the least accessible areas, or to at least see only cattle production as cattle can transport themselves to market rather than requiring a truck for transport.

Landowner Migration and Property Sale in Models of Household Behavior

None of these models explicitly address the out-migration of property owners or the sale of the property. However, we can develop their implications for the examination of patterns of migration and sale, and associated land use change. The traditional household production model allows little room for migration, predicated on the absence of land markets and the presence of an intergenerational household making joint decisions on the property. While some children might leave as they grow older, the core household/family unit is argued to stay on the property. Thus, migration should be a rare event. In addition, households can be argued to be replaced by households following the same logic of production, based on household demographic composition. Thus, we expect to see little migration (and no sale) and no land use change associated with migration or sale unless the migration or sale results in a different age-sex composition of the household. Without directly modeling the association between age-sex composition change and land use change, we might expect that new households are on average younger and therefore have higher available labor. We would then expect to see the sale of a property associated with a decrease in forested area and an increase in area in production, primarily in the production of food crops.

Our social learning approach suggests a consideration of frontier development and the diversification of households spatially. As the frontier develops, a family specializes in production of certain crops (or animals) on a given property, but diversifies production by specializing in production of other crops on other properties. In other work, we also argue for diversification across sectors of the economy, examining the ways in which households diversify into the urban sector as well as into other products in the rural sector. This suggests several patterns of migration and sale, and associated changes in land use. It is important to note that the patterns we are describing here are associations and not causal relationships, in large part because the causal relationships are so difficult to identify empirically. If households are diversifying across products within the rural economy by purchasing multiple properties, we would expect to see land use change at the property level to reflect the property-level specialization. However, migration off of the property without a sale should not be associated with land use change, as it reflects a property that has gotten to a self-sustaining state. Neither should a sale be associated with land use change. As the frontier we are studying is well-developed, buyers can select a property that matches their desired land use and not have to pursue a great deal of land conversion after purchase.

The Von Thünen and modified household production models assume a rational economic actor as a decision-maker for the household, and assume that this actor has access to full information about the returns to a variety of land uses. They maximize their production subject to the constraints of their property (location and biophysical characteristics of the land) and to their capital and labor constraints. Thus, on average, land use should not be influenced by sale (assuming that changes in the capital and labor constraints are randomly distributed) and migration should increase labor constraints unless it reflects a relaxing of capital constraints (meaning the household can purchase labor to substitute for the lost labor of the out-migrant owner).

Study Area

The Altamira study area is located along the Transamazon Highway and was opened for settlement by the Brazilian government in 1970. It was advertised as an ideal farming area because of the reputed high soil fertility, and settlers were heavily recruited by the government (Moran 1981). The land was partitioned into 100 hectare properties, each with 500 meters of road frontage along feeder roads intersecting the Transamazon every five kilometers. This settlement pattern resulted in what has come to be called the traditional Brazilian “fishbone” pattern of land clearing, with clearing occurring along the Transamazon and along the feeder roads and with corridors of forest remaining at the backs of properties (Arima et al. 2005).

The study area is characterized by rolling topography, making mechanized grain production (e.g. soy, rice) less viable than pasture or perennial tree crops like cocoa. Water is plentiful in much of the study area, enabling cattle ranching and rain-fed crops. As a result, the rapidly cleared old growth forest was replaced primarily by pasture or perennials (sometimes with one or more seasons of annual crop production before planting of pasture or perennials). Looking across the study area today (mid-2000s), secondary growth is rare, reflecting the absence of fallow rotations for annual crops and the rarity of abandoned land. The time period covered by the data used in these analyses was a period of transition, between higher levels of secondary growth and the current landscape.

Analyses in this paper use social survey data collected in Altamira in 1997 and 1998, and again in 2005. The original sample was designed to be representative of households settling in the region at various time points. To select this sample, the research team began from a property grid obtained from the Instituto Nacional de Colonização e Reforma Agraria (INCRA) which was in charge of the settlement scheme. After extensive field correction of this property grid using Global Positioning System (GPS) technology to precisely locate the actual boundaries of properties, the time of initial settlement for each property was identified using satellite imagery linked with property boundaries in a Geographic Information System (GIS). Properties were considered to be settled when five hectares of forest clearing was visible on a given property in the satellite image. From this grid, a random sample of properties, stratified by time of initial settlement, was selected. The male owner of each sampled property and his wife were then interviewed. Interviews with the male owner (or a proxy, the person who was most knowledgeable about agricultural practices on the property) covered the current and past land use, the biophysical characteristics of the property, agricultural practices, and various characteristics of the household. The interviews with the female head of household (the wife of the owner or a proxy respondent who was knowledgeable about the demographic and economic characteristics of the household) covered the current and past demographic composition of the household, fertility and migration histories, and various other economic and demographic characteristics of the household.

Study Design and Modeling Strategy

The following analyses utilize longitudinal property and household data from Altamira. The original sample (described above) includes 402 properties, stratified by time of first occupation, on which the owning household (head and spouse) was interviewed in 1997 and 1998. In followup data collection in 2005, we revisited the sampled properties and reinterviewed the owners. We reinterviewed any owners who were anywhere in the study area in 2005, including those who had moved and those who had sold their properties. For those who left the study area or died, we have information about where they went (if they moved). We also followed up on the property, interviewing the current owner (or owners) if the property had been sold (and/or subdivided) and interviewing all households resident on the property. We thus have a panel of properties (and, for other papers, a panel of households) with information about what happened to the previous owner. We also have the ability to distinguish moves without selling from moves with selling, allowing us to examine the importance of each independently.

In each survey wave, we collected detailed survey information about land use on each property, including both sketch maps and tabular data. We incorporated sketches, in the field use of satellite imagery, and traditional survey questions to collect the highest quality data on land use from owners and residents of surveyed properties. In 2005, we focused on the measurement of current location among surveyed individuals and among those outside the study area, as well as measuring the ownership of the property. This allows us to create reliable measures of land use at the two time points, and of migration (distinguishing rural and urban destinations) and property sale between the two time points.

We use these data to estimate two sets of models. In each, the property is the unit of analysis. First, we estimate the relationships between a set of household and property characteristics in 1997/1998 and the status of the property owner in 2005: dead, moved without selling, or moved and sold. These are multinomial logistic regression models. We tested models with the status disaggregated into rural versus urban destination among those who moved, creating a five-category outcome variable. However, these models did not improve upon models with the three-category measure so we present the three-category model here. We then include the full five-category measure of the status of the owner in 2005 relative to 1997/1998 as a covariate in OLS models of the change in the area in forest, change in the area in pasture and change in the area in perennials.

These models are clearly not causal models, as each contains endogenous right-hand-side variables and the migration or sale might well have happened after the land use change in the land use change models. However, we are primarily interested in the patterns of land use change associated with migration and sale to assess their role in such land use change. The endogeneity and temporal order patterns are in fact interesting, because we care equally about the results if land use change is a preparation for sale or a consequence of sale, or if the move to a city is associated with urban employment because of a prior decision to invest in education or urban employment.

Sample and Measurement

Our key variables are land use and migration/sale status. We measure land use by aggregating the respondent's reports on the area of the property in a variety of land uses. The questionnaire and sketch maps focused on locally important categories (*pomar* [orchard], *pasto* [pasture], *roça* [garden, usually mixed subsistence crops], *mata* [forest], *capoeira/juquira* [secondary growth on previously cleared land]). We then aggregated this into forest (including only primary forest, not older secondary growth), pasture (aggregating all reported pastures along with areas that were secondary growth, but were used as pasture), perennials (including cocoa, coffee, black pepper, and a few other less common crops), and annuals (gardens, rice, beans, manioc, and a few other less common crops). Analyses of annuals produced no significant relationships, due primarily to the small variance across properties in the area in annuals (and the resulting low and meaningless variability in change in area in annuals). We therefore present only models of change in area in forest, pasture, and perennials.

The 2005 status of the 1997/1998 property owner vis-à-vis the property is a compilation of information from completed questionnaires and informants. We started by going to the property to look for the old owner. If he (or she) was not living there anymore, we collected information on where he currently lived and whether he still owned the property (or information that he had died). We further collected information on the new owner, if the property had been sold or transferred to someone else, applying surveys to the owner and all residents of the property whenever possible. If no one was present on the property, we returned several times to inquire further, and we solicited information from various neighbors on each visit. In this way, we collected information on the current location of most (398) of the previous owners of the properties we were able to visit (we visited all but two of the original 402 properties, as two were inaccessible). In some cases, the information was only that they were no longer in the study area, but in the vast majority of cases we have information on the município (if in Pará) or state (if outside Pará) to which he went, and on whether the destination was rural or urban. Combining the information from the completed questionnaires of previous owners who were located in the study area and the information from informants on previous owners who had died or were out of the study area, we created a six-category measure of current status: 1) stayed on the same property; 2) moved to an urban area (without selling); 3) moved to a rural area (without selling); 4) sold and moved to an urban area; 5) sold and moved to a rural area; and 6) died.

Control variables in our analyses include the land use in 1997/1998, measured as the areas in forest, pasture, perennials, and other. These variables are created in the same way as the 2005 land use. The other category is a residual that captures a combination of annuals, secondary growth, house and yard, and water. Control variables (all measured in 1997/1998) also include the number of households on the property, and the number of properties owned by owner. For the owner and his household, we measure whether the owner had a non-agricultural occupation, the age and marital status of the owner, and the size of the owner's household. For the property, we measure whether the closest city is accessible from the property in the rainy season, and the percent of property with *terra roxa* (the most fertile type of soil in the area). All of these measures are taken from the surveys completed with the owner and his/her spouse in 1997/1998.

Our analytical sample for the multinomial logistic regression of the current status of the 1997/1998 owner includes 393 properties (of the original 402) with information about the current location of the owner and complete information for predictor variables. Our analytical sample for the land use change analyses includes 378 properties with information about the current location of the owner, and about land use at both time points. Tables 1 and 2 show descriptive statistics on all variables included in each of the analyses (for the analytical samples).

The descriptive statistics in Table 1 show that moving and selling are not rare events. Of the analysis sample for the moving and selling analysis, 15% of owners moved without selling while just over 14% moved and sold. Urban destinations were more common among movers and sellers, but an adequately sized group of movers (4% of total sample) and sellers (6.3% of total sample) were found in urban destinations in 2005. The remaining statistics in Table 1 reflect the characteristics of the study area. The largest average land area (48.61 hectares) was in forest in 1997/1998. Properties had substantial average area in pasture (38.47 hectares) and relatively little area in perennials (8.12 hectares) and other uses (11.74), primarily fallow areas to be used later for pasture. The majority of properties (77%) were accessible to the city in the rainy season. The characteristics of the household similarly reflect the population of settlers. The average owner was over 50 in 1997/1998, with an average household of 5 people. The vast majority were married or in a union, and very few worked outside of agriculture. The number of properties (rural properties in the study area) owned varied a great deal, but the average was only 1.54, reflecting the fact that the majority of owners were smallholders with a single property.

Table 2 shows the same distribution of characteristics of properties and owners, with minor differences because of the smaller sample available for the land use change analysis. This table also shows the average changes in land area in forest pasture and perennials in the analysis sample. These are consistent with the overall story of settlement and frontier development in the Amazon, showing the increasing area in pasture (average increase of 13 hectares) and decreasing area in forest (average decrease of 16.6 hectares). The average change in area in perennials shows that perennials were occupying slightly less area at the end of the observation window, an average of 2.3 hectares less per property. However, these averages mask the heterogeneity of experiences across properties. Table 3 shows the average change in area in forest, pasture and perennials by the status of the owner in 2005. While the averages show a decrease in forest and an increase in pasture on all types of properties, the magnitude varies. Properties from which the owner moved to another rural property (without selling) show substantially less deforestation (average decrease of only 6 hectares in forest) than do others. These properties show a similarly lower increase in pasture and show a small but positive change in perennials.

Results

Table 4 shows the multinomial logistic regression analysis of moving, selling or dying (with staying on the property as the comparison group). As we would expect, older owners and those who were not working outside agriculture (which we can assume is associated with good health) are more like to be dead than to be in the same property in 2005 as in 1997/1998. Interestingly, only one of our covariates is significantly related to moving without selling (versus staying). This is the number of household members, with larger households associated with staying on the property rather than moving elsewhere.

The covariates associated with selling and moving tell a more convincing story, a story of potentially wealthier farmers who have invested in other areas (urban or rural) selling their properties and moving. The more properties owned by the owner in 1997/1998, the more likely he is to have sold and moved by 2005, versus staying on the same property. Similarly, those who worked outside of agriculture (generally in the city) in 1997/1998 translated that work into the sale of the property and moving between 1997/1998 and 2005. These factors combine with a non-investment in the property of residence, with lower areas in pasture associated with higher odds of selling relative to staying.

The question then is whether the relative lack of association between land use in 1997/1998 and migration or sale means that migration and sale are independent of land use change completely, or whether migration or sale are associated with land use *change* over the 1997/1998 – 2005 interval. We turn now to the models of land use change over this period. Table 5 shows the OLS models of change in areas in forest, pasture, and perennials over that time period as a function of 1997/1998 land use, status of the owner in 2005, and characteristics of the property. These models show that, controlling for property accessibility and soil quality, the stocks of land in the various uses in 1997/1998 and the status of the owner in 2005 are significantly associated with land use change in the 1997/1998 – 2005 interval. Properties with a larger stock of forest in 1997/1998 see more deforestation (more negative change in the area in forest) and conversion to pasture (more positive change in the area in pasture), but less conversion to perennials. These effects are substantial, with each additional hectare of forest in 1997/1998 associated with just under half a hectare more of deforestation and .4 hectares more of increase in area in pasture.

The stocks of pasture and perennials have smaller impacts on the change in land uses over the interval. Each additional hectare of pasture in 1997/1998 is associated with a .1 hectare higher increase in the area in pasture and only a .02 hectare higher increase (or lower decrease) in area in perennials. The stock of land in perennials is only significantly associated with change in land in perennials, with an additional hectare of land in perennials in 1997/1998 associated with .2 hectares higher increase (or lower decrease, as the average change is negative) in area in perennials. These results suggest that, in addition to a common conversion of land from forest to pasture or perennials, properties are becoming specialized in one form of market-oriented production. Pasture encourages more pasture formation; perennials encourage more perennial planting.

Interestingly, properties from which the owner moved to an urban area (with or without selling) do not show significantly different changes in any of the three land uses from properties on which the owner stayed. Moving to a rural area, however, is associated with less deforestation (more positive change in forest area) and greater investment in perennials. The owners who moved to a rural area without selling show a particularly large positive coefficient in the forest change model. These patterns suggest that there exists a group of properties on which the owners specialize in production in the rural sector. Cattle ranching, the end goal of the pasture formation, is not exclusively a rural pursuit. It is both a productive activity and a status symbol among the urban elite as well as among rural residents. Perennial production, in contrast, requires more onsite supervision (even when hired workers or sharecroppers do the physical labor) and commitment to the rural area. It is unclear how much of this is cultural and how much reflects actual requirements of the activity, but one rarely sees a cocoa farmer who lives several counties or states away while it is not uncommon to see such a cattle rancher.

Conclusions

Contrary to the archetypal story of Amazonian settlement and frontier development, property turnover in our analysis is not associated with deforestation or pasture conversion. Moving or selling are not associated with prior low levels of forest area on a property, nor is a negative change in forest area associated with moving or selling. In contrast, the only significant association is between migration within a rural area and preservation of forest area. This suggests that the traditional narratives of settlers clear-cutting and then moving on, or settlers beginning the clearing which is then completed by large ranchers buying up many small properties, are not playing out in our study area. While it is possible that our study area is unique, given its status as a “model” settlement area with relatively high levels of government investment, it is also possible that the traditional narratives have overlooked the dynamics operating at the micro level.

We then turn to how our results fit with the prominent micro level theoretical approaches to households, migration and land use in the Amazon. The household production models reviewed above, including the Chayanovian model and modifications allowing for the availability of labor markets and market production, suggest that migration and sale would reflect higher returns to the household in another location. Our results are consistent with that argument, as the selling is associated with non-agricultural employment and with the ownership of additional properties. In other work, we focus more closely on the migration decision of different household members and how well these conform to extant theories of migration. Here we only focus on the consistency of the migration with the theories of land use and then examine the association of migration or sale with land use change.

The land use models can be divided into two groups based on their predictions about this association. Models based on Von Thünen and arguing for the importance of biophysical characteristics of the property in determining the appropriate land use predict no association between migration and land use change. Land use is based on accessibility and land suitability for various uses. While we expect to see land use change over time, reflecting changing exogenous demand and prices, technology, and accessibility, we do not expect migration to be related to this land use change. Our results stand in contrast to this argument. Out-migration without sale is associated with retention of forest and expansion of perennials, while out-migration with sale is associated with expansion of perennials. Further arguing against these approaches, our admittedly weak measures of accessibility and soil suitability have generally non-significant coefficients (accessibility) or coefficients opposite from expectations (soil quality).

The models that do predict an association between migration or sale of a property and land use change are those that focus on the social or demographic characteristics of landowners. We do not explicitly test the household life cycle model, which has dominated much of the writing in this area, in this paper. It would argue that the changes in the household characteristics over time, whether due to aging, sale, migration, or other factors, drive changes in land use. We could explicitly test this model for a subset of our properties for which we have complete information on all resident and owning households in 2005. However, this model has largely been disproven and is unlikely to explain the results that we find for the associations between migration within the rural area and land use change.

In contrast, the theoretical model that we have been developing focusing on social learning and the development of social networks and institutions in the frontier is consistent with the results we find, though the results by no means prove the theory. The migration results show that moves and sales reflect investments elsewhere in the region, while the land use results show specialization at the property level along with diversification at the family level. Migration without sale is associated with investment in perennials in the original property with at least minimal investment in a new property. This result begs the question of whether the diversification is merely spatial diversification (addition of a property to the portfolio or moving to a completely new property and abandonment of old property) or is also diversification across crops. Our field observations suggest that families diversify by investing in perennials in one or more properties and investing in cattle in the remaining properties.

Our next step must then be to consider these family-based linkages between disparate physical locations, and how such linkages influence land use change. Specifically, we must consider the new and old properties of those farmers who moved within the rural area without selling, but we must also consider the multiple properties owned by those who did not move. In addition, we must consider the joint decision-making across households within a family. This paper only considers the properties owned by a single household, usually the patriarch of the settler family. However, as the frontier ages we see join decision-making and sharing of risk and returns across households both within and across generations. Siblings each specialize in one or more economic activities, but these are often coordinated between the siblings in consultation with the father. These social structures create patterns across the landscape that reflect social organization in addition to biophysical variability, requiring us to model this social organization to understand and project land use change.

Table 1. Descriptive Statistics on Sample for Analysis of Moving/Selling, Altamira 1997/1998 and 2005, N=393 Properties.

[redacted]

Table 2. Descriptive Statistics on Sample for Analysis of Land Use Change, Altamira 1997/1998 and 2005, N=378 Properties.

[redacted]

Table 3. Bivariate Relationship between Property Owner Status in 2005 and Land Use Change 1997/1998-2005, Altamira, N=378 Properties.

	Average Change in Land Use (ha) (2005 Area - 1997/1998 Area)		
Property Owner Status (2005)	Forest	Pasture	Perennial
Dead	-16.50	10.78	-5.61
Stayed	-17.72	14.05	-2.39
Moved to Rural Area without Selling	-6.00	4.50	0.25
Moved to Urban Area without Selling	-14.23	9.35	-1.79
Sold and Moved to Rural Area	-15.89	16.93	0.72
Sold and Moved to Urban Area	-15.38	11.85	-2.73

Table 4. Multinomial Logistic Regression Analysis of 2005 Status of 1997/1998 Property Owner, N = 393.

	Contrast					
Variable	Dead vs. Stayed		Moved vs. Stayed		Sold vs. Stayed	
Property Characteristics						
Accessible in Rainy Season (1=yes)	-0.149	(0.54)	0.548	(0.43)	-0.0700	(0.33)
Area in Other (ha)	-0.00343	(0.017)	0.000935	(0.012)	-0.00637	(0.013)
Area in Pasture (ha)	-0.00386	(0.0065)	- 0.000486	(0.0028)	-0.0215 *	(0.0088)
Area in Perennials (ha)	-0.0269	(0.020)	-0.00532	(0.012)	-0.033 +	(0.019)
Area in Forest (ha)	- .016 *	(0.0078)	-0.00213	(0.0056)	-0.00948	(0.0070)
Characteristics of the Property Owner and His/Her Household						
Age of the Property Owner (years)	0.0785 *	(0.022)	-0.0184	(0.013)	-0.0191	(0.015)
Property Owner Married or in Union (1=yes)	-0.234	(0.84)	-0.135	(0.64)	-0.669	(0.50)
Number of People in Household	-0.117	(0.095)	-0.26 *	(0.087)	-0.0285	(0.074)
Property Owner Works Outside Agriculture	-34.18 *	(0.45)	0.637	(0.51)	1.022 *	(0.50)
Number of Properties Owned	0.193	(0.12)	-0.292	(0.24)	0.280 *	(0.10)
Constant	-5.258 *	(1.76)	0.738	(1.18)	1.068	(1.10)
Likelihood Ratio Chi-Sq (df)			11471.51 (30)			
N			393			

Note: Robust standard errors in parentheses.

* p<0.05 + p<0.10 (two-tailed tests)

Table 5. OLS Regression Analysis of Land Use Change 1997/1998 – 2005, N = 373.

Variable	Forest			Pasture			Perennials		
Property Owner Status (2005)									
Stayed (Reference Category)									
Dead	-4.811	+	(2.87)	1.273		(4.04)	-2.862		(2.74)
Moved to Rural Area without Selling	7.249	*	(2.78)	-6.223		(4.46)	2.944	*	(1.41)
Moved to Urban Area without Selling	1.667		(3.40)	-3.580		(5.20)	0.455		(1.30)
Sold and Moved to Rural Area	2.463		(3.39)	3.578		(4.77)	2.907	*	(1.03)
Sold and Moved to Urban Area	-2.626		(2.43)	1.901		(3.71)	-0.161		(2.32)
Property Characteristics									
Area in Forest (ha), 1997/1998	-0.464	*	(0.10)	0.398	*	(0.13)	-0.0193	*	(0.0093)
Area in Pasture (ha), 1997/1998	-0.0597	+	(0.034)	0.0966	*	(0.047)	0.0213	*	(0.0069)
Area in Perennials (ha), 1997/1998	0.0296		(0.068)	0.0519		(0.086)	0.102	*	(0.046)
Area in Other (ha), 1997/1998	0.223	*	(0.094)	0.21	+	(0.11)	-0.0959	*	(0.043)
Percent of Property with *terra roxa*	-0.0214		(0.022)	-0.0568	*	(0.029)	-0.0894	*	(0.019)
Accessible in Rainy Season (1=yes)	-3.045		(1.86)	5.221	*	(2.19)	0.177		(0.98)
Constant	8.430		(6.97)	-15.72	+	(8.87)	-0.187		(1.04)
Observations	378			378			378		
R-squared	0.53			0.38			0.15		

Note: Robust standard errors in parentheses

* p<0.05, + p<0.1 (two-tailed tests)

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