Deforestation and Land Use in the Amazon

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Land Use Patterns on an Agricultural Frontier in Brazil

Insights and Examples from a Demographic Perspective

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This chapter is part of an ongoing research endeavor on trajectories of land use change associated with frontier settlement at the household/property level in the Altamira region of Pará State, Brazil. The research is being carried out by a multidisciplinary team at the Anthropological Center for Training and Research on Global Environmental Change at Indiana University with funding from the National Institute of Child Health and Human Development (NICHD). A central concern of the project is to link landscape change to demographic dynamics of frontier settlement through the use of remotely-sensed imagery and household/property surveys. It is a micro-level approach with a view to uncovering specific mechanisms of land use change that, in the medium to long run, shape landscape change. Much current remote sensing analysis deals with broad-based landscape change and focuses on "hot spots" of deforestation. These changes are often associated with macro- and aggregate-level processes (for example, road construction, migration flows, economic trends, and government policies). In contrast, a micro-level approach can evaluate and enlighten our understanding of how households and communities, embedded in these macro-level processes, transform the landscape during a generation-long process of frontier occupation, settlement, and consolidation. This micro-level demographic approach, focusing on the process of transformation, provides an alternative, yet complementary, perspective on landscape changes taking place in frontier regions of the Amazon and possibly in other agricultural frontiers.

The chapter progresses as follows. First, we outline some of the conceptual and methodological issues in linking demographic and remotely-sensed image analysis. We then illustrate the potential of a demographic perspective through a discussion on period, cohort, and age effects for understanding and disentangling causal mechanisms underlying processes of landscape transformation. Next, we discuss a conceptual framework for linking the demography of families to agricultural strategies as well as to levels and patterns of deforestation and afforestation. Briefly we outline a research strategy we developed (property grid development and sampling) in order to link household/farm data to remotely-sensed data. Finally, we provide a discussion of our results on demographic changes over the course of frontier occupation and settlement among our sample of 402 households in the Altamira region.

Issues in Linking Sociodemographic and Remotely-Sensed Analyses

In recent years there has been increasing interest in promoting multidisciplinary research on environmental change that integrates social and natural sciences. Land use/land cover change has served as a unifying theme for this integration that combines remotely-sensed data and analysis with social science perspectives and methods. The recent volume *People and Pixels*, edited by Liverman and others (1998), highlights the promise of this kind of research. Many articles discuss the rationale, possibilities, and limitations of this work as well as provide excellent examples of particular research strategies. At the risk of oversimplification and omission of the range of research possibilities, it is useful to outline some of the conceptual and methodological issues that emerge in this process of bringing different research communities and perspectives together in research on land use/land cover change. Table 6.1 and the following discussion provide a schematization of these issues as they relate to incorporating quantitative socioeconomic and demographic research strategies and data into this research agenda.

Recent technological innovations in software and hardware facilitate the collection, organization, manipulation, and analysis of spatially-distributed data (Michalak 1993). The methodological toolboxes of Global Positioning System (GPS) and Geographical Information Systems (GIS) greatly facilitate the integration of social science research into the land use/land cover research agenda. Nevertheless a series of conceptual and methodological issues must be addressed to make this research more fruitful. While overall interest in landscape conditions and changes is the focus of

Table 6.1. Conceptual and methodological issues in linking demographic and remote sensing analysis

	Socioeconomic/Demographic	Remote Sensing
Focus	Land Use	Land cover
Methodological concerns	Units of observation and units of analysis (events, individuals, households, social groups, communities, social organization/mode of production, regions, nations)	scale Resolution Spatial boundaries
Emergent implications	Who are the social actors of interest and what are their spatial dimensions?	
Data sources	Censuses and sample surveys	Remotely sensed imagery
Spatial dimensions		
Census:	Political/administrative boundaries (census blocks, tracks, counties . . .)	Pixels (with varying resolution)
Surveys:	Possible point or boundary definition with GPS equipment	
Coverage		
Census:	Periodic complete coverage	Complete temporal and spatial coverage
Surveys:	Incomplete coverage	
Potential problems		
Census:	Problem of ecological correlation, spatial units with urban bias (urbanized areas are small and rural areas are large) Heterogeneity within large spatial units may be greater than heterogeneity among units	
Surveys:	Incomplete coverage	

the research, approaches to these questions vary substantively across disciplinary lines. We can say that environmental scientists working with remotely-sensed data focus primarily on land cover and typically think about landscape changes. Their smallest unit of observation is the pixel. The different bands of reflectance of pixels can be analyzed as continuous variables over space or be grouped into patterns and classes of land cover. Resolution, scale, and amount of information gathered (for instance, different bands of reflectance) of remotely-sensed data vary by types of sensors carried by satellites and result in pixels of different sizes.

One distinct feature of satellite image analysis is that these data represent complete coverage for an area. Frequent passes by satellites can provide multiple images for analysis over time. These characteristics of remotely-sensed data provide great flexibility for spatial and temporal data reorganization and analysis. Geographers, ecologists, and other environmental scientists working with spatial analysis and satellite imagery are particularly sensitive to issues of scale, resolution, boundaries, and areal units in their investigation of biophysical phenomena.

In contrast, social scientists involved in this research agenda are interested in land use. Often we infer "use" implicitly from analyses of land cover, but land use and land cover are distinct concepts. Land use is concerned with social, cultural, and economic behavior; it involves human actors and actions as they affect, shape, and organize the environment. Quantitatively oriented social scientists, who work primarily with census and sample surveys, are sensitive to another set of conceptual and methodological issues in their analysis of social actors. Important to this discussion is the distinction between units of observation, units of analysis, and levels of analysis. Units of analysis are events, individuals, families, households, social groups, communities, and other forms of social organization, while data for these analyses are primarily from census and sample surveys of individuals and households, or aggregations of these. Mismatch between units of observation and units of analysis can lead researchers to make heroic assumptions and misleading inferences when we try to infer community-level processes from individual-level data, or conversely, make inferences about individuals or households from community-level data or population aggregates. A pivotal concern emerges from this brief comparison of approaches: Who are the social actors of interest and what are their spatial dimensions?

Standard approaches involving census data or sample surveys have different potentials and limitations for research on land use/land cover change. Individual- and household-level socioeconomic and demographic data from censuses are typically only available for samples (data from U.S. Public Use Microdata Samples [PUMS], for example). These individual- and household-level data generally lack any spatial reference other than "rural," "urban," and possibly "suburban," as characteristics of these social actors, groups, or communities. Given the general lack of spatial references and incomplete coverage, these census samples are not useful for making the spatial links with land cover data.

Census tabulations by various areal units (blocks, block group, tracks, counties, clusters of counties) provide other possibilities but are not without additional challenges. Unlike individual data formats, census tabulations provide aggregate measures of population characteristics for areal units; the difficulty emerges in establishing relationships among variables within the population. A common approach is to infer relationships through the comparison of spatial units. In doing so we run the risk of inferring relationships at the individual level that may be considerably different from, or even contradict, observed correlation at the aggregate level. This potential problem is commonly known as "ecological correlation" (Robinson 1950).

Linking these standard sources of population data also presents other hurdles when we consider the analysis of land use/land cover. First, small areal units devised for administrative and political purposes and used in census tabulations, such as block or census track data, have a decidedly urban bias. Areal units are small in urbanized areas and increase in size in rural and remote areas. The size of areal units for administrative and census purposes is typically associated with population density. These characteristics of data organization limit the possibilities for dealing with many aspects of the human dimensions of land use/land cover change.

GIS is important for overlaying and extracting aggregated data between various layers of information at the level of the larger areal units. This aggregation of information (derived at the level of the pixel) increases the heterogeneity within our units of analysis. In addition to the potential problems of ecological correlation and comparability among differently-sized areal units, these studies have to contend with how well spatial units match spatial boundaries or clusters of land cover types. If heterogeneity is greater *within* areal units vis-à-vis heterogeneity *between* areal units, analytical potential is reduced. The possibilities of these studies will depend on the extent of overlay between the various areal units and the degree of heterogeneity within and between them. Studies that make use of census data and satellite information will certainly increase as these data sources become more readily available, but may be relegated to macro-

scale analysis of municipalities and provinces as a result. There are already several noteworthy examples that illustrate possible directions of this kind of research (Rosero-Bixby and Palloni 1998; Wood and Skole, 1998). We raise these issues as concerns and potential pitfalls that must guide research strategies and clarify the range of possible research endeavors. These studies will no doubt be important for understanding the human dimensions of environmental change on a very broad scale but will be limited for understanding and making inferences about land use/land cover change at meso- and micro-levels where individuals, families, and communities directly influence and change their environments.

Another set of questions arises when we consider the use of social science surveys for research on environmental change: What are the spatial dimensions of human actions, actors, or social groups? How do we construct spatial boundaries for our units of analysis? In some social contexts these questions may be more readily discernable than in others. Where the use of land by individuals and households (or even communities) varies across large areas, defining areal units of observation and analysis may prove very difficult. We raise these observations as a result of past work by ourselves and colleagues on households, nutrition, and land use in the traditional maize region of central Yucatan (Gurri 1997; Sohn et al. 1998). In this region, land is held collectively among *ejido* community members and a rotational agriculture of slash-and-burn is practiced. In this context, where use rights are not fixed spatially by clear boundaries, linking households to land use/land cover is difficult. Similar difficulties may apply when defining spatial boundaries for areas that have multiple uses and multiple user groups. Entwisle and her colleagues (1998) similarly note the difficulty of linking land cover data in contexts where land use is fragmented and dispersed and local populations live in nuclear settlements. In research situations such as these it may be inappropriate and/or impractical for research endeavors to link spatially defined land use/land cover change to individuals, families, and households. For practical and theoretical reasons, analysis may more appropriately proceed at the community level with comparisons of many communities and their surrounding areas. Indeed many of the research questions about land cover change in these contexts may be more appropriately addressed at the community level, where individuals share opportunities and constraints on land use together. (See Entwisle et al. [1998] for further discussion on conceptual and methodological issues in linking data for analysis of land use/land cover change.)

In addition to these more conceptual issues related to units and levels of analysis, it is important to ask how to incorporate information from sample surveys with satellite image analysis. Unlike censuses, remotely-sensed data, or other commonly used GIS data layers, sample surveys typically provide incomplete coverage of the population of interest. As such they are of limited value in standard approaches to GIS-based research and analysis. The gains to be made in this kind of endeavor are best accomplished by the back-and-forth sharing of information between sample surveys and remotely-sensed data through the use of GIS methods. The project presented in the remainder of this chapter is an example of some of the possible avenues of this kind of research. With regard to many of the difficulties of integrating social and environmental research on land use/land cover discussed above, our study area is ideal: it is characterized by a grid-like distribution of farm properties where land use takes place within clearly defined boundaries and households live on their farms. Our primary units of observation and analysis are households and their farm property. In particular, we are interested in how the demography of families affects the adoption of different agricultural strategies, and how these, in turn, affect the rates and patterns of deforestation on a family farm.

In the following section we outline the need for more intensive work on micro-level processes to better understand the process of frontier occupation, settlement, and consolidation as it affects landscape changes.

Landscape Transformation and Frontiers: Insights from a Demographic Perspective on Change

Much of the current research with remotely-sensed data (such as Multi-Spectral Scanner [MSS] and Thematic Mapper [TM] imagery) deals with broad landscape change. Linking these changes to specific socioeconomic, political, and demographic processes is at the heart of our research agenda, yet frequently we speculate on the causal nature of these changes by making loose references to macro-level processes such as annual variation in climatic conditions, changes in credit policy, economic trends, and migration. Much of this speculation does not explain the spatial variation and intensities of transformation observed in the satellite imagery. One useful avenue of research, suggested here, is to distinguish between patterns of change in different stages of frontier occupation, settlement, and consolidation as opposed to focusing on "hot spots" of recent deforestation. A useful conceptual tool is the demographic perspective of cohort, age, and period effects in the analysis of agricultural frontier communities.

To illustrate the point, consider changes in areas associated with land

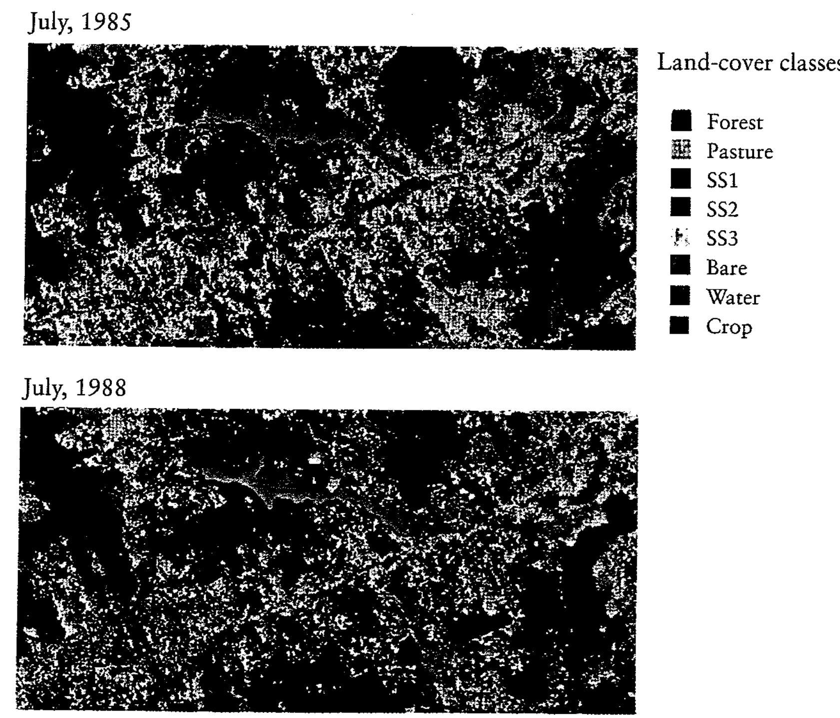

Fig. 6.1. Simple comparison of 1985 and 1988 TM land cover change to illustrate issue of period vs. cohort/age effects

cover classes for a subsection of the Altamira region (Mausel et al. 1993) in figure 6.1. For this small area, centered on kilometer 23 of the Trans-amazon Highway and settled in the early 1970s, approximately 55 percent had been deforested by 1985 and a large proportion of this area was covered by bare ground (presumably being prepared for cultivation) or was in pasture. Less than 20 percent of the area was covered in some stage of secondary vegetation, primarily less than twelve years old. After three years, in July 1988, an additional 4 percent of the area had been deforested, the area in pasture and bare earth was much smaller, and secondary succession had grown to nearly 40 percent of the area. This dramatic shift from pasture and bare soils to secondary succession signals important changes in activities in the area.

In ascribing causal factors to these changes, it is easy to speculate on the changing role of credit policies during the period, the importance of cocoa in the mid-1980s, and its decline in subsequent years. An alternative explanation, without knowledge of the area, might include generalized field or farm abandonment. All of the explanations noted above are what demographers refer to as *period effects*. Alternative hypotheses might include the investigation of possible *age* and *cohort effects* in our inquiries about these changes. A pure age effect would reflect similar patterns of farm development among households by length of time on the farm property irrespective of when they arrived or what types of policies were being carried out. A cohort effect is one in which some event or process common to a group of households results in a distinctive pattern of behavior. Timing of arrival on the frontier is a clear marker for defining cohorts and exploring the idea of possible cohort effects. Individuals and households settling during the same period experience many similar opportunities and constraints of the frontier that are markedly different for others arriving later (for example, off-farm employment opportunities, road conditions, market possibilities). These shared experiences within a cohort vis-à-vis other cohorts may result in quite different agricultural strategies from those suggested by either age or period effects.

In the above illustration, might the increase in secondary succession represent a cyclical fallow management strategy of these farm families? Is this observed process a secular trend possibly reflecting length-of-time trajectories of land use associated with the development of family farms? Could the shift be associated with the aging of these farm families fifteen to twenty years after initial settlement? Or, might these changes be specific to a particular cohort of occupation and settlement? Incorporating this demographic perspective in research may aid in disentangling many of the specific causal mechanisms involved in land cover change as well as provide us with a better understanding of processes of frontier expansion and consolidation.

Figure 6.2 illustrates some of the methodological concerns for carrying out this kind of inquiry. The first, upper diagram (A) exemplifies inferences from cross-sectional approaches. Information on current characteristics of households and farms is collected at one point in time. Typical comparisons among these households/farms involve inferences related to length of residence on the property (age effects) and farm formation. The question that arises is whether initial differences between cohorts (capital, and origin, or timing of arrival, for instance) may explain many of the variations in land use. Similarly, we face difficulties in understanding the relative roles of age effects and period effects if we study only one cohort of settlement (diagram B) in that all the households/farms experienced the same period effects (credit change, market conditions) at

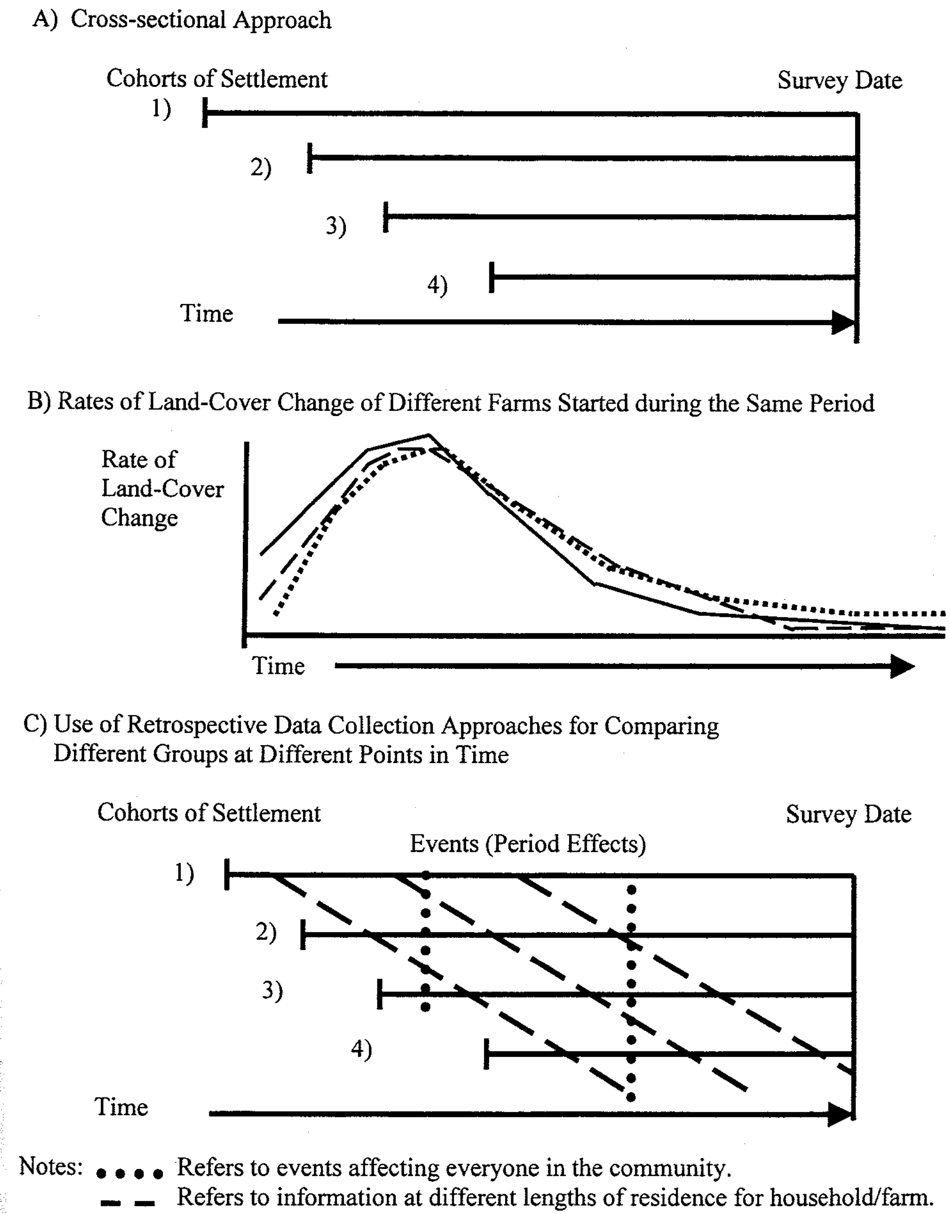

Fig. 6.2. Examples of the use of demographic concepts of cohort, age, and period effects to understand the processes of landscape transformation

similar stages of farm formation and length of residence. Does, for example, an increase in deforestation on these farms indicate a change in market conditions or credit policy (period effect), or does it merely reflect a time or age effect associated with farm development? In order to disentangle cohort/age and period effects, we have to compare different groups at different points in time (diagram C).

Implicit in this approach is the view that households and farms have trajectories of development related to length of settlement. We also assume that land use is shaped, but not determined, by changing public policies, market conditions, and economic trends. The landscape can be seen as a mosaic of farm properties at different stages of formation. Farm development on an agricultural frontier is a process often spanning a generation or two. Research at the household and farm level has been the focus of attention of much fieldwork in the Amazon over the past two decades. Econometric and ethnographic studies have detailed the complex ways in which land use decisions are made. Factors commonly mentioned include environmental characteristics such as topography and soils, public policies affecting credit and market conditions, and an array of household characteristics such as origin, initial capital at time of settlement, and agricultural experience in the region. What is less known is how farm development takes place over the long term. Are there trajectories of land use associated with different agricultural strategies or, as we suggest in the following section, with the labor composition of households and their domestic life cycle? Sensitivity to the conceptual issues of cohort, age, and period effects may help to disentangle this complex web of relationships at the individual farm level while also enlightening our understanding of landscape change.

Development of a Conceptual Framework

During the course of previous fieldwork, Emilio Moran observed that neighboring farms often had quite dissimilar patterns of land use. Some of these differences could be explained by variations in initial capital of incoming migrant families, their origin, and their experience with agriculture and with the region (Moran 1977, 1981). Access to water, distribution of soils, and distance to markets typically are shared among neighbors and provide less insight into these different patterns of land use (among neighbors), while they appear to be important at the broader landscape level. Household labor appears to play a significant role in the different agricultural strategies (Moran 1977). Households with abundant labor often became involved in perennial crop activities such as fruit trees, coffee, cocoa, and black-pepper. Smaller families focused their activities on creating pasture and raising cattle. Reflections on this process suggest that land use, while strongly affected by environmental and economic considerations, is influenced by the labor supply of households over the course of the domestic life cycle of these families. Recent settler families in a frontier are predominantly composed of small young nuclear households, with a head couple in their mid-20s to early 30s and a few young children. Their initial agricultural activities involve clearing a small area of forest (three to five hectares) to cultivate annual crops such as rice, beans, and manioc for consumption and for sale in local markets. Each year additional forest areas are cleared and previous plots are either left in fallow, formed into pasture, or planted in perennial crops. The shift to cattle and perennial crops is typically a slow process that involves high initial capital and labor cost, and the gains from these activities will only be reaped in later years. Typically, perennial crops will not provide any returns to the family for three to five years, while acquiring cattle may be an important capital-saving strategy. Cattle can be quickly purchased or sold depending on household needs. While the initial labor and capital costs for raising cattle and planting perennial crops may be similar, the medium-run labor needs appear to be quite different. Perennial crops require continual maintenance to obtain high yields, and the periods of harvesting and market preparations are long and labor intensive. Most well-established farms rely on sharecropping arrangements involving as many as two to five other families, depending on the area and number of trees. In contrast, raising cattle on established pasture typically involves only one or two adult male household members supplemented by temporary laborers for periodic cleaning of pastures. On larger ranches a handful of permanent laborers may be employed. Pasture maintenance is not a trivial issue in the Amazon given the rapid regrowth of secondary succession (Moran et al. 1994, 1996). Weeding and burning fields is typically carried out during the dry season rather than year round, and these maintenance cycles vary from one to three years. Replanting pastures with new grass seeds has a much longer cycle. The availability of certain soils and water sources, capital, and/or credit, and the amount of household labor affect the shift to either perennial crops or raising cattle, or remaining in annual cash crop activities. With the exception of soils and water there may be varying degrees of substitutability between capital, credit, and labor. In the early stages of farm development most farm families exhaust their initial capital reserves (Moran 1981), and incorporating the labor of ado-

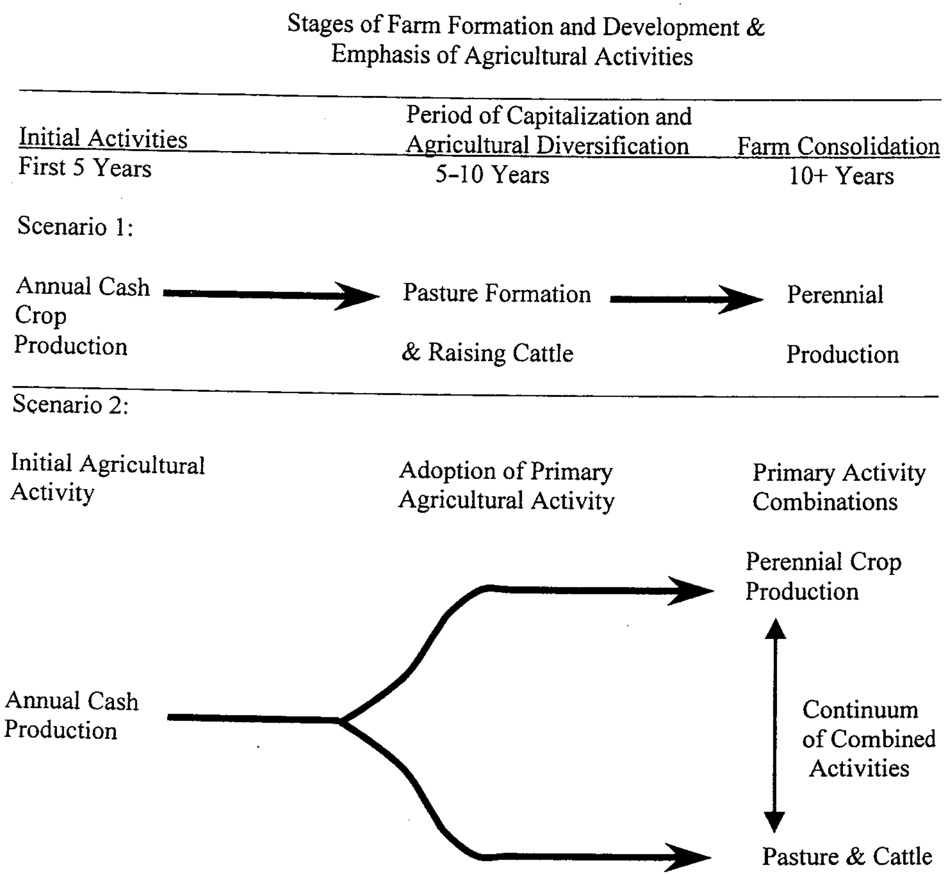

Fig. 6.3. Possible scenarios of farm-level and land use trajectories

lescents and teenage children may be a determining factor along with credit possibilities for furthering farm investments.

This discussion suggests two possible scenarios for land use trajectories, illustrated in figure 6.3. The first (scenario 1) suggests an overall trajectory in which households use cattle raising as a capital-accumulating strategy for subsequent shifts to perennial crop activities. The second scenario (scenario 2) proposes that households begin a process of differentiation following the initial period of occupation, toward an emphasis on either cattle grazing or perennial crop production. In reality families typically practice combined strategies with varying concentrations on an-

nual crops, perennial crops, and cattle-raising activities. The question that emerges is whether these shifts in land use reflect ad hoc decisions based on credit availability and market prices, are constrained by soil distribution and water sources, or form part of a long-run land use trajectory.

As noted earlier in this section, household labor composition appears to have an important influence on these strategies and outcomes. In figure 6.4 we present a conceptual framework that highlights the role of household labor over the domestic life course of households as these relate to land use/land cover trajectories for an agricultural frontier. The approach is seen as a complement, rather than an alternative, to approaches focusing on environmental and economic factors, and is linked to the earlier discussions on cohort, age, and period effects. It does emphasize the role of household labor in the short- and long-term patterns of land use/land cover change. In the upper section of the diagram, we suggest a pattern of land use over the course of farm occupation and development. The thickness of each line represents the level of activity in each of five primary land use activities. These stages of land use (upper x-axis) are linked to different stages of a domestic life cycle of households (left-side y-axis) as young nuclear families migrate to the frontier, age over time, and then dissolve into multigenerational and second-generation households as children reach adulthood. The diagonal from the upper left to the lower right corners represents our general expectation of farm formation and the domestic life course of households. Initial activities of these migrant families involve clearing forest and planting annual cash crops for consumption and for local markets. As they establish perennial crops and pastures (stages II and III), rates of deforestation decline, fallow management increases with the growth of secondary succession, and families increasingly focus their energies on perennial crop production and raising cattle. In stages II and III, some families are expected to continue their investments in perennials while others emphasize development of pasturelands and raising cattle. The former group maintains cattle as a risk management strategy but focuses primarily on expanding their long-term crop activities. The decision to shift to one or the other of these activities, we hypothesize, is related to composition of household labor. In contrast to cattle raising, perennial crop activities provide few potential short-term gains; initial returns to this investment will begin in three to five years, and the investment does not provide the liquidity associated with owning cattle. Shifts to perennial crops are, in the short run, a risky endeavor. The presence of adolescent and teenage children may be important for this shift to perennial crops.

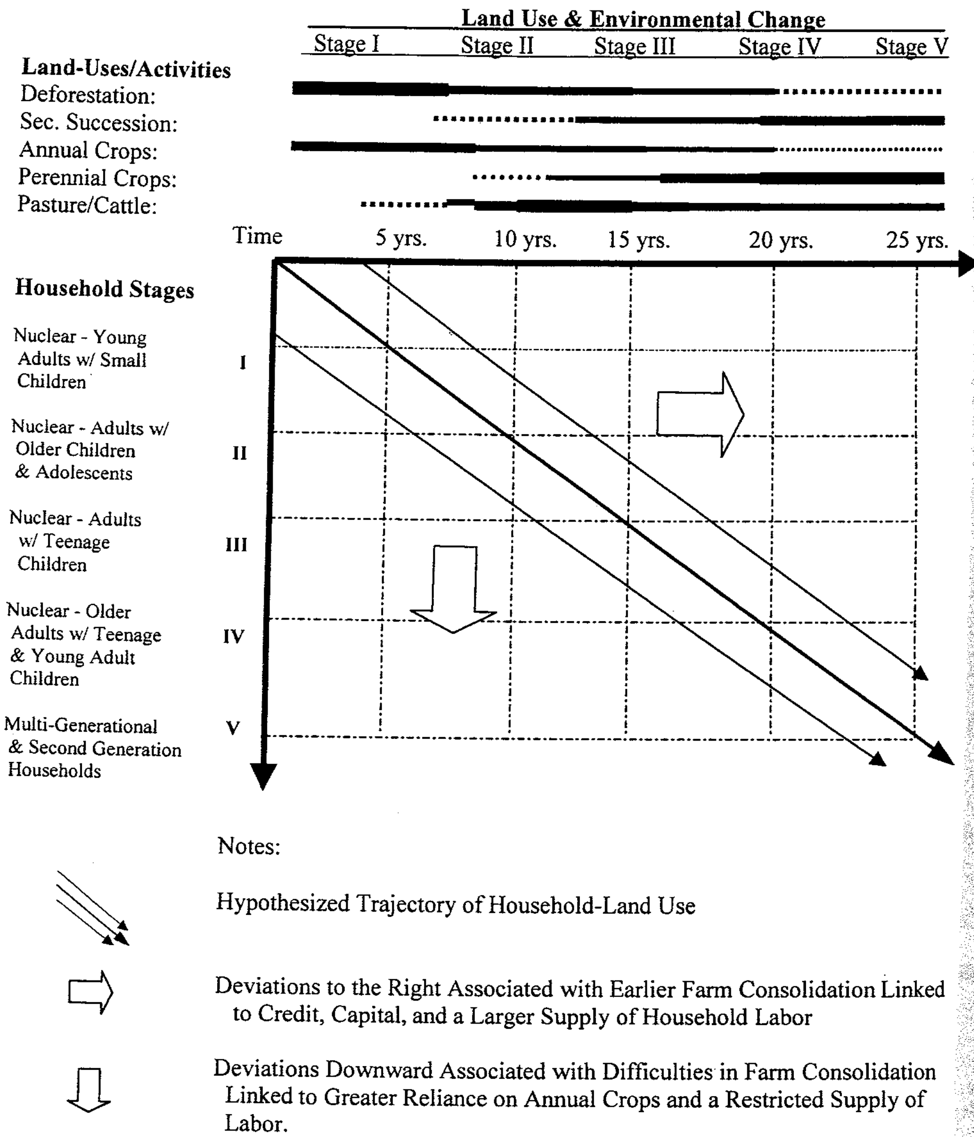

Fig. 6.4. Conceptual framework of household transformations, land use, and environmental change

In this conceptual framework other factors such as initial capital, credit, and large supplies of labor are expected to increase the pace at which households are able to consolidate their farm activities in perennial crop production and raising cattle. This consolidation, we suggest, implies a slowing of deforestation on the farm and an increase in the growth of secondary succession. We anticipate that this tendency will be strongest among households focusing their attention on perennial crop activities. In contrast, other households that have had difficulty in initiating cattle raising and/or perennial crops as a result of restricted supply of labor, less initial capital, or limited access to credit will concentrate on continued annual crop activities to meet their immediate household needs. These households are expected to continue deforesting larger areas of their farm as they shift plots every couple of years. The long-run implication of a dominant emphasis on annual crops is that a larger area is deforested in much less time and secondary vegetation may cover a much larger area of the farm property.

This discussion of our conceptual framework is cast at the individual household and farm level. In a much broader view it is a description of what might be considered *demographic and environmental transitions* that accompany frontier occupation, settlement, and consolidation. The following series of questions addresses specific elements of our research propositions.

(1) What is the demographic composition of colonist families at the time of settlement over the course of frontier occupation? Are the gender and age compositions of incoming migrant families similar or do they change at different stages of frontier expansion?
(2) How does the age and gender composition of household labor change over the domestic life cycle as a result of fertility, mortality, marriage, and migration? More specifically, are fertility and marriage important for incorporating additional labor? What happens with adult children? Do they remain on the farm, migrate to new agricultural frontiers, or seek wage employment in nearby towns?
(3) How do changes in the labor composition of households, interacting with capital and credit and environmental variables (for instance, soil quality, topography), affect the particular strategies of forest clearing, fallow management, and agricultural activities? For example: Do small families tend to favor cattle grazing over time? Do large families slowly invest in agroforestry, rubber, coffee, blackpepper, and cocoa? How does the timing of credit (during the course

of farm development) affect land use decisions among these families with different amounts of labor?

(4) What are the implications of these farm strategies for the patterns and levels of deforestation, secondary succession, and forest regrowth? In other words, does the farming strategy based primarily on cattle grazing lead to greater levels of deforestation? Does a shift to agroforestry and perennial crop production lead to slower rates of deforestation and foster forest regrowth of other areas once cleared? What are the implications of continued rotating of annual cash crop production for the pattern and overall level of deforestation?

Succinctly stated, the research agenda is to evaluate how the demography of families affects the agricultural strategies pursued on family farms and how, in turn, these strategies differentially affect patterns and levels of deforestation and secondary succession.

Research Strategy, Activities, and Sampling

With a view to this research agenda, our work over the past two years has been devoted to three realms of activity: (1) remotely-sensed data analysis; (2) development and implementation of a sample survey with farm families; and (3) integration of remotely-sensed and survey data through the use of GIS. Much of our work is based on previous activities carried out at the Anthropological Center for Training and Research on Global Environmental Change (ACT) with vegetation inventories, ground-truth fieldwork, and MSS and TM Landsat satellite image analysis (see Moran and Brondízio 1998). During the last two years additional land coverages have been incorporated (see Brondízio et al., chapter 5 in this volume) to create a time series of land cover for our study region dating back to 1970 with ten points in time. In shifting our attention to the level of households, spatially identifying farms and households has been a primary concern in the current project. A property grid with 3,800 properties has been developed for overlaying remotely-sensed imagery and for other GIS layers (such as topography, drainage systems, distribution of soils, and cost-distance surfaces relating farms to local markets and road networks). This grid of farm properties serves to demarcate spatial boundaries for our household units of observation and analysis, and for developing a sampling frame for survey fieldwork. Data can be extracted from remotely-sensed imagery at the property level for cross-sectional and longitudinal analysis of land cover change. A description of the property grid development and the potential for analysis at the farm property level can be found in McCracken and others (1999). Brondízio and colleagues present an analysis of these types of data in chapter 5 with a view to disentangling cohort/age effects from period effects and developing general patterns of land cover change at the farm level.

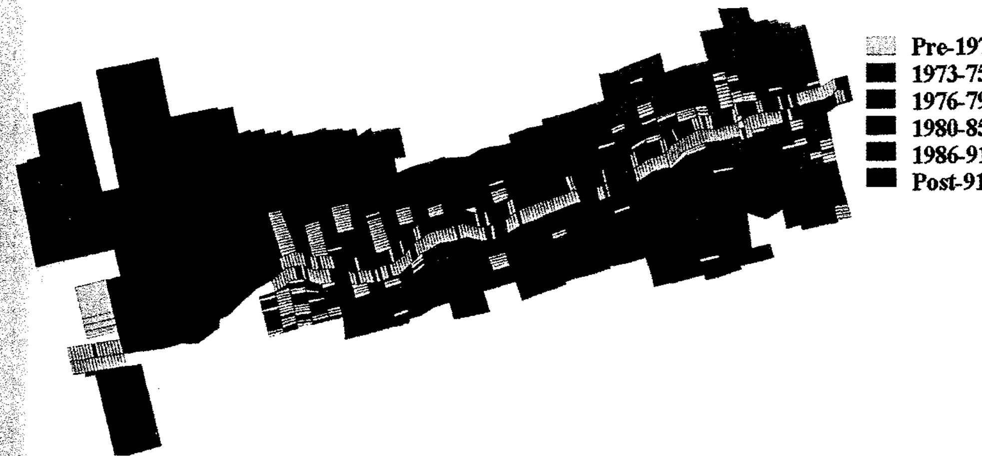

Fig. 6.5. Stratified sampling frame: cohorts—timing of initial clearing

Given our research focus on cohort, age, and period effects at the household/farm level, the use of a property grid with remotely-sensed imagery proved a useful strategy for temporally stratifying our sampling frame. In this colonization area a disproportional number of farm properties were settled in the early to mid-1970s. Data on the area deforested between each land cover classification allowed us to temporally ascribe a period of initial settlement to each farm lot, resulting in five strata or cohorts of settlement. We used an area of five hectares cleared between satellite images as a signal of the period of initial settlement. Equal numbers of household/farms were randomly selected from each cohort of settlement for inclusion in our sample survey. The purpose of this stratification was to ensure that we interviewed families who arrived at different times over the course of frontier settlement. Figure 6.5 illustrates the distribution of cohorts of settlement for the grid of properties. Figure 6.6 shows the distribution of households interviewed by their time of arrival on the farm property. During the course of fieldwork, teams of interviewers used Garmin GPS equipment to reach the sampled farm property and its family to carry out in-depth retrospective demographic histories of

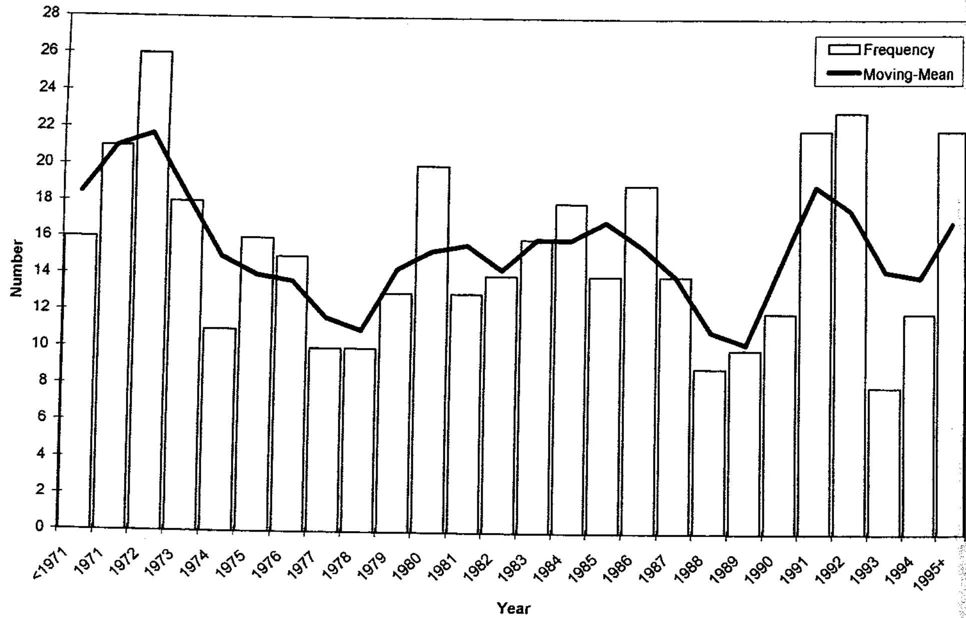

Fig. 6.6. Distribution of households by year of arrival on current farm

households and their members and land use histories. In December 1998 we completed our surveys with 402 households in this region.

In the following section we focus on general aspects of demographic change found with the sample survey data to illustrate the importance of household labor for agricultural strategies and to highlight the dramatic demographic processes that have accompanied frontier settlement over the course of thirty years in the study area.

Demographic Change on an Agricultural Frontier: Evidence from Altamira

Gathering socioeconomic and demographic information on households and their members, coupled with detailed retrospective data on entries and exits of household members, permits the reconstruction of the evolution of household composition since these families arrived on the frontier. Analyses can be carried out at the individual level on fertility, mortality, marriage, and leaving the household. In later analyses we will link these data to information gathered in land use histories to evaluate if and how

agricultural strategies vary with the changing composition of households. The use of these data with retrospective data on different types of labor involved in farm activities illustrates the important role of household labor to farm investments and development. A simple calculation of the number of persons multiplied by the number of years each person worked on the farm for different types of labor—household, permanent, and sharecropping—provides a dramatic illustration of the labor that goes into developing these frontier farms. These calculations of person-years worked are presented by cohort of arrival on the farm in figure 6.7. As the figure illustrates, household labor, on average, accounts for a large share of labor on these farms. Unfortunately we are at present unable to present estimates of temporary day labor for previous years given problems of interview recall. Preliminary analysis of current uses, and field observation, indicate that use of day labor is quite common but varies substantially by household composition, agricultural activities, and length of time on the farm. Of the labor sources considered here, family labor represents 84 percent of labor inputs for the oldest cohort of settlers and over 93 percent for the most recent settlers. On the oldest farms, settled before 1976, family labor represents a household investment of more than 90 person-years of work. In no case does either sharecrop or permanent labor

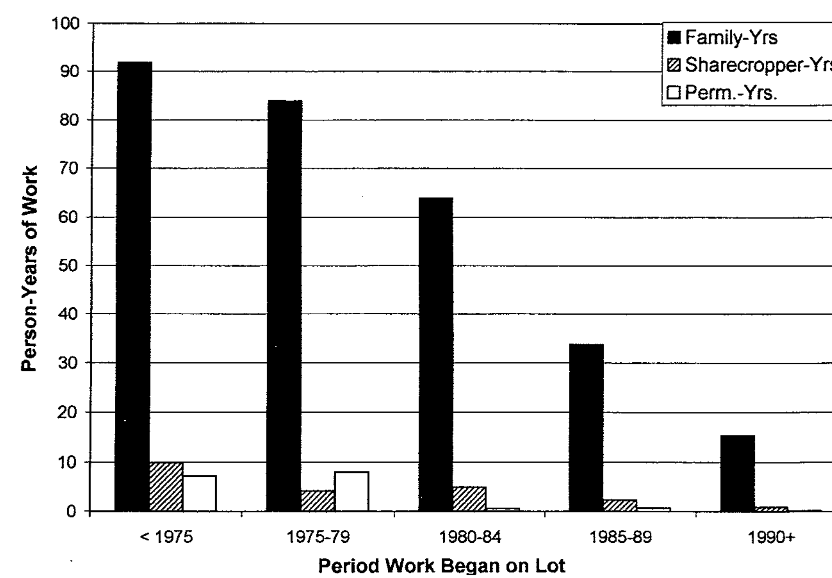

Fig. 6.7. Person/years worked by type of labor and period of arrival

represent more than 10 percent of labor inputs, and each is associated with households and farms that have been established for a longer period of time.

If the role of household labor is as important as these figures suggest, then the size, age, and gender composition of households can be expected to play a role in the amount and types of agricultural activities pursued. In the land use histories we also gathered information on the types of activities (domestic, child care, gardening, care for animals and cattle, milking, felling trees, burning, planting, weeding, harvesting, and processing of agricultural products) each member of the household had been involved

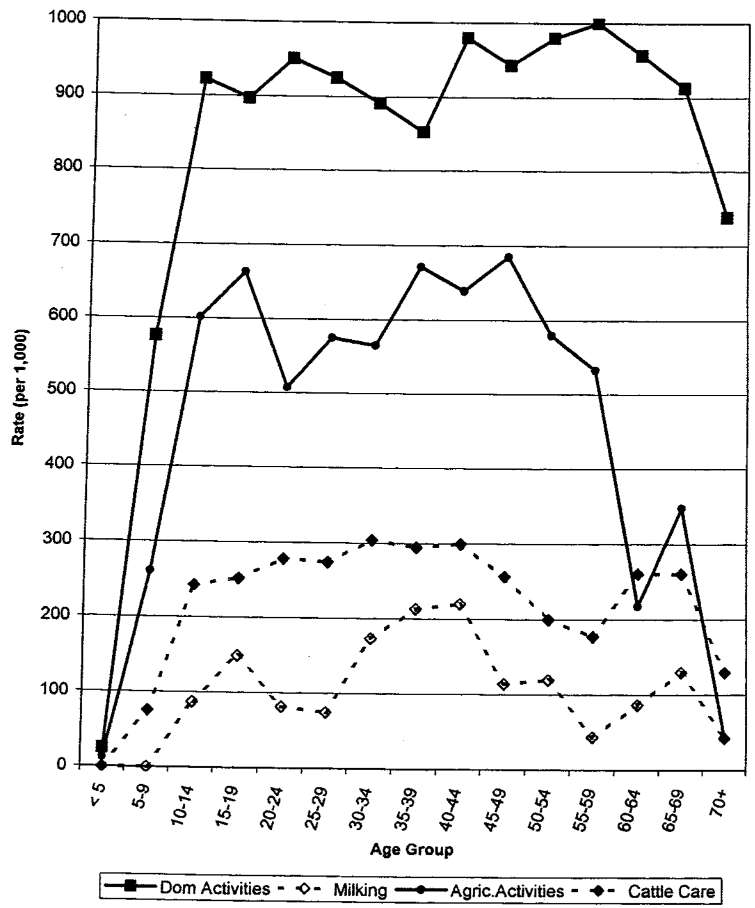

Fig. 6.8. Age-specific rates of participation in domestic and agricultural activities on the farm by gender. Current household members, sample survey, Altamira. (a) Female.

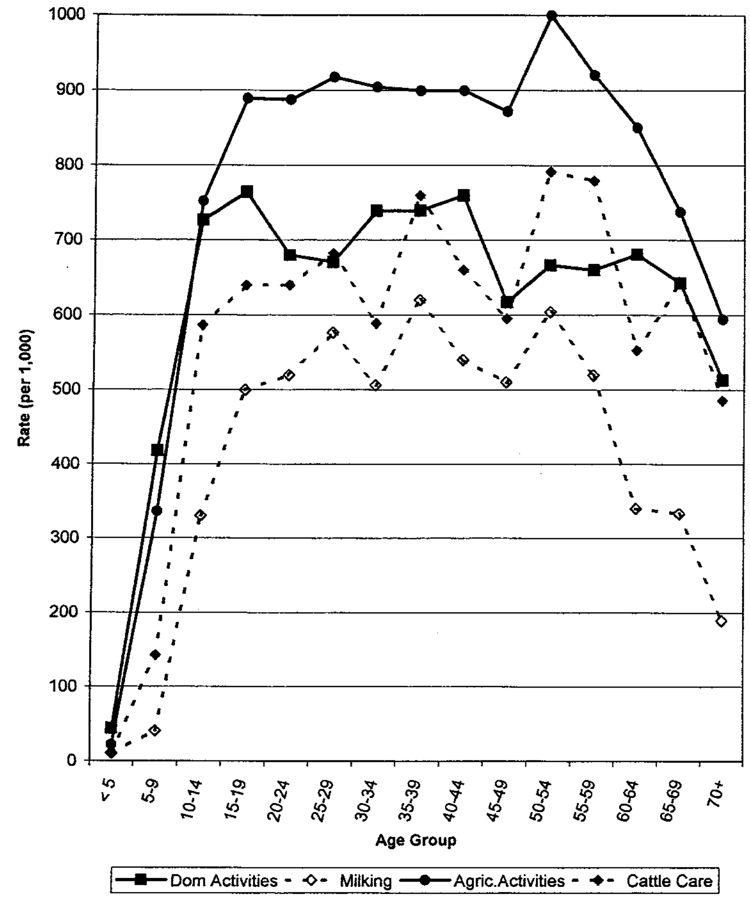

Fig. 6.8. (b) Male.

in, on a regular basis, during the last twelve months. Examination of these age and gender rates of participation (fig. 6.8) suggests that agricultural activities are not strictly segregated. Rather, there is a general flexibility in the activities that different members of a household can be involved in. These rates do show a general pattern of involvement in certain activities by age and gender, which can be expected to vary in households of different composition and/or socioeconomic conditions and over the course of farm development.

In general, young adolescents take on domestic duties early and are involved with caring for younger children and tending to animals (for example, chickens, ducks, and other yard animals). The gender composition of these activities is disproportionately female and increases as teenage boys are incorporated into caring for cattle and milking, where they are twice as likely to be involved as their female counterparts. Gender differences are most pronounced throughout adulthood for activities such as felling trees, burning, and weeding, where men are three to four times more likely to be involved. The gender differences are less marked in harvesting and processing agricultural products, in which a larger share of women are involved. The pattern of participation in these agricultural activities typically declines for women in their 20s as they begin childbearing, increases again, and then declines after age 45. For men, participation in these activities reaches a high level by their early 20s, remains high through their early 50s, and then steadily declines. There are no clear gender differences in the making of manioc flour or in gardening near the house although gardening activities tend to increase with age.

Given the importance of household labor to farm investments, and the general patterns of activities associated with age and gender, household composition over time is expected to affect the types of investments and direction of agricultural strategies. An analysis of the population composition of our sample illustrates the demographic transformations taking place on the frontier and the changing composition of labor among farm families over the course of the domestic life cycle. Figure 6.9 presents three population pyramids that highlight the processes of entries, exits, and aging among these households. The first two pyramids show the age and sex composition of household members at the time of arrival while the third presents the current age composition of both former and current household members. In all three pyramids the inner pyramid indicates the number of individuals who currently remain in the households. The first pyramid indicates that as families arrive on the frontier their households are composed of predominantly young members, and slightly more males than females. This pattern of male-dominated sex ratios, even among infants and children and through the early 20s, suggests selectivity in favor of male labor as families migrate to the frontier. This pyramid also illustrates the important role of household dissolution as children age and begin leaving the domestic unit.

In the second (middle) pyramid, the outer bars indicate the arrival age of members joining these families and suggest some unexpected household labor strategies. Children born into the household after arrival on the lot, not included in this figure, comprise the largest group of new household members (72 percent of joiners) as might be expected. Excluding these children, the majority of new members in these households are women between the ages of 15 and 24. Combined with insights from other analy-

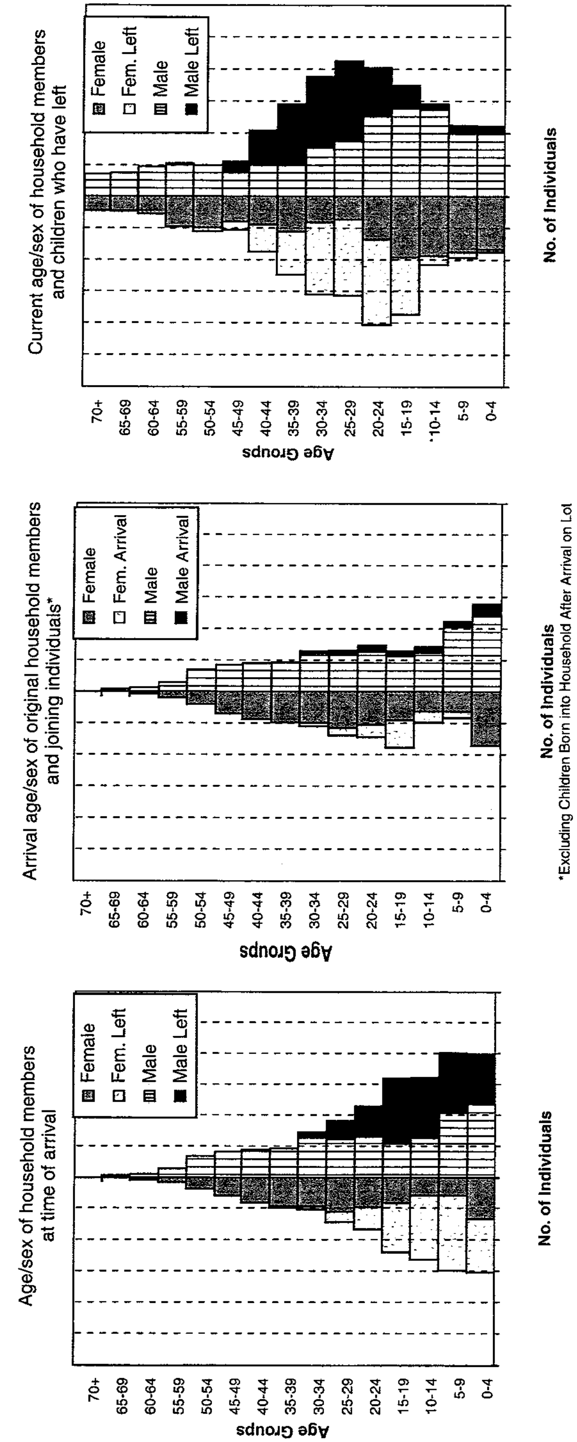

Fig. 6.9. Age and sex pyramids of current household members, joining members, and leaving members.

ses, we interpret this as a pattern in-marriage of women associated with a male labor retention strategy. The third pyramid illustrates both the male selectivity in initial family migration as well as this male retention strategy. A comparison of the ratio of males and females between the ages of 10 and 24 illustrates the disproportionate number of young males in these farm households. Moreover, a much larger share of female children between the ages of 10 and 19 has already left the household. Further examination of the survey information indicates that young women are more likely to leave their households of origin for schooling as well as for marriage. Often, better-off households will establish a second residence in a nearby town so that children can continue their education. This pattern typically favors higher education among girls over boys in our sample. Out-migration of young women through marriage is also quite common and typically involves moving to another farm household, setting up a new farm as part of marriage, or, more often, leaving to live in a nearby town with a husband. Young men are more likely to stay on the family farm, eventually taking over responsibilities from their parents, or, in conjunction with their original household, purchasing another farm property.

The comparison of the first and third pyramids, showing ages at the time of arrival and interview respectively, illustrates the overall loss of labor from children as these become young adults and shows the general aging process of households on the frontier over time. In figure 6.10 we present a cross-sectional approach to these data to further illustrate demographic dynamics on the frontier: current age and sex composition is presented by the period of arrival of these households on the farm property. This cross-sectional comparison suggests a general aging process among households over time. The age and sex composition of families arriving within the last eight years (first pyramid) exhibits a similar pattern to that noted above when looking at the age of arrival of all households surveyed; it is young with a broad base. The second pyramid shows the age and sex composition of families who settled on their farm lot 9 to 14 years before the survey. It, and subsequent pyramids, illustrates a general aging process, with an increasingly larger share of elderly members and older children and teenagers, and shows a general reduction in fertility with few children under the age of five. The third pyramid suggests a growing share of older households with greater shares of adolescent and teenage children, while the fourth and fifth pyramids, for households arriving prior to 1979, illustrate the increasing importance of multigenerational and second-generation households with a growing share of young adults. The fifth pyramid is composed of a large share of members over the age of

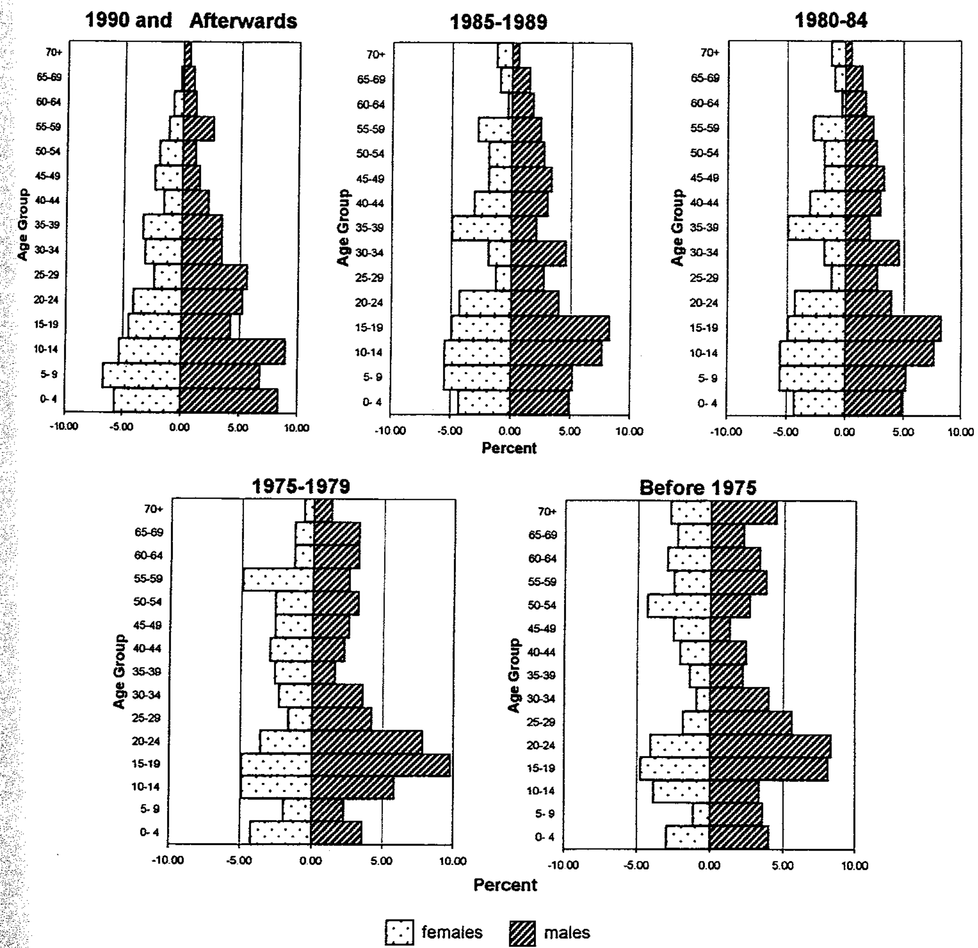

Fig. 6.10. Age and sex pyramids by period of arrival of the households. Sample survey, Altamira region, 1998.

sixty, a large share of young married couples and single male adult children, and an initial third generation of children now under the age of five.

Demographic processes of frontier occupation and settlement are dynamic and complex, yet these processes are often neglected in understanding frontier settlement or the resultant transformations of the landscape. As households age on the frontier, and as farms are consolidated and passed on to children, we can expect to see different patterns of land use.

Family Labor, Agricultural Strategies, and Deforestation: A Discussion of Preliminary Results

In the preceding pages we laid out some general responses to the first two sets of research questions presented above. The overall goals of the previous section were to highlight the role of family labor on these frontier colonist farms as well as to illustrate the dynamic demographic processes that accompany frontier expansion and consolidation at the local level. In this section we briefly discuss preliminary results from the land use survey collected with each farm family. Farming strategies among our sample of farm families indicate a wide range and diverse set of combined activities in annual and perennial crops and pasture for raising cattle. Preliminary analyses show that environmental, economic, and household labor composition are important to agricultural strategies as measured as the percent of agricultural operational area devoted to each of the three broad categories of activities (annual crops, perennial crops, and pasture formation and cattle grazing) on these farms. Emphasis on pasture and cattle, for example, is significantly related to poorer quality soils, access to water, and having had agricultural credit. Percent of productive, or operational, area devoted to pasture is also significantly positively associated with the number of previous owners of the lot, and significantly negatively associated with mean annual family labor. In contrast, percent of operational area in perennial crop activities is significantly and positively related to area with *terra roxa* soil and with the amount of family labor (also see Moran et al., chapter 7 in this volume), but is negatively associated with number of previous owners of the lot. These results support our general propositions about the relationship between family labor and agricultural strategies. Furthermore, preliminary analysis with the household sample data reveals that the percent of farm lot deforested since arrival on the lot is significantly associated with percent of operational area devoted to pasture, having had credit, and, most importantly, with the number of years on the farm lot. The same measurement of deforestation at the farm level was also negatively and significantly associated with having other farm lots and other off-farm activities. When we analyzed percent of farm area deforested since arrival using dummy variables for each of the agricultural emphases (annual, perennial, and pasture) based on percent of the operational area in each, controlling for these other variables (credit, previous owners, other properties, and off-farm activities), we find that farms with an emphasis on pasture and cattle grazing have between 8 and 10 percent more of their farm lot deforested. Farms with an emphasis on annual crops were not significantly different from those with an emphasis on cocoa, coffee, and black-pepper. Similar conclusions were reached in an analysis of remotely-sensed data at the farm level (McCracken et al. 1999).

These results, based on a cross-sectional approach, provide strong yet preliminary support for our general propositions outlined earlier. Further analysis of the retrospective data, we anticipate, will provide evidence on how the changing composition of household labor leads to particular combinations of agricultural activities, and how these, in turn, lead to different patterns and intensities of deforestation at the farm level. A particular aim of this more detailed questioning of the retrospective data is the understanding of how period, cohort, and age effects shape land use on individual farms and how these, in turn, play out in the patterns of deforestation at the landscape level. In chapter 5, Brondízio and colleagues provide further insights into and evidence on the relative roles of period, age, and cohort effects on patterns of deforestation in their analysis of remotely-sensed data at the property level.

Conclusions

In the initial section of this chapter we summarized several of our concerns about linking quantitative social science, demographic approaches, and census data with analysis of remotely-sensed data. Common constraints have to do with the problem of ecological correlation, spatial units with urban bias, and great heterogeneity within these typically large spatial units vis-à-vis the heterogeneity among units. Of particular concern are the issues of (1) identifying who the social and economic actors of interest are, and (2) identifying the spatial extent of their actions. Sample surveys, particularly with the innovations in GPS and GIS, offer additional opportunities but are not without shortcomings. Sample surveys typically involve incomplete coverage of the actors of interest, but data and findings can be shared back and forth between analyses of survey data and that of remotely-sensed data. Following this overview and discussion, the chapter focused on the analysis of frontier landscapes.

In the context of analyzing land use/land cover change on agricultural frontiers we suggest a new approach that draws on the demographic concepts of period, cohort, and age effects. Typical land cover change analyses, which incorporate demographic data and processes, focus on the important roles of migration and natural growth. These are often cast at the aggregate level. In the particular context of frontier settlement, the concepts of period, cohort, and age effects may provide additional insights for investigating the complex processes of transformation in these agricultural frontiers as individual families migrate to, occupy, and transform plots of forest into family farms. The landscape is a mosaic of farms initiated during different periods, and farm formation and development is a long process often taking place over a couple of generations. Environmental factors, economic trends, and government policies shape the agricultural strategies that individual families pursue at different stages of farm development. We suggest that, in addition to these factors, households and farms are shaped by their labor composition over the course of their domestic life cycle and result in a range of land use trajectories with direct long-term consequences for frontier landscapes.

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