Deforestation and Land Use in the Amazon

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Trajectories of Land Use

Soils, Succession, and Crop Choice

Emilio F. Moran, Eduardo S. Brondízio, and Stephen D. McCracken

Interest in the causes of land use change at local and regional scale is longstanding in the social sciences (Glacken 1973; Sauer 1962; Steward 1955; Thomas 1954; Turner et al. 1990). Population growth, migratory currents, landlessness, developmentalist policies, road building, and climate change are among the many causes suggested for large-scale changes in the Amazon (Denich 1991; Fearnside 1986; Gash et al. 1996; Moran 1981; Skole et al. 1994; Smith 1982; Wood and Skole 1998). Whereas *land cover* describes the land's physical attributes (for example, forest, grassland), *land use* expresses the way such attributes have been transformed by human action. To understand land use, it is critical that we take into account resource perception (and reality); the structure of opportunity costs; the range of management practices known and historically practiced; how they may be constrained by available labor, land, or capital; and the levels of risk a population may be willing to entertain.

Studies of human perception of environment have contributed important findings to our understanding of changing landscapes. How a farmer understands or classifies a soil plays a role in shaping his pattern of land clearing, land use, and land abandonment (Behrens 1989; Conklin 1954; Moran 1977; Tucker et al. 1998). If a soil is "good for bananas" it is likely that a population will implement land use consistent with this cultural knowledge when such a soil is available to the individual who possesses this information (Behrens 1989). In the same manner, some soils are commonly classified as being inappropriate for agricultural use and are never cultivated, leading to a pattern of land use for those patches different from that of adjacent areas. Likewise, understanding how a local population classifies or distinguishes between different types of land cover embodies a set of cultural criteria that shape vegetation use and land use trajectories (Brondízio 1996; Brondízio et al. 1994, 1996). Among populations with long residence in a location and precise knowledge of forest land and soils, the use of vegetative criteria for selecting soils for different uses is common and highly accurate (Behrens 1989; Conklin 1954; Moran 1975 and 1977). This use of criteria is less true among frontier migrants since they lack site-specific cultural knowledge relevant to their new biophysical environment.

In this chapter we show that soil fertility differences account for a significant proportion of the variance in observed rates of secondary succession regrowth and therefore in the rate of carbon sequestration following deforestation of primary forests in the Amazon, and in the land use trajectories of farmers. In the more fertile sites we have studied, we find at least a twofold difference in biomass over nutrient-poor sites, a difference that amplifies in the second and third decade of regrowth. We have also found significant differences in species composition, with the more fertile sites having greater tree species diversity because of greater canopy development, but lesser total plant species diversity because of lesser understory development (Moran et al. 2000; Tucker et al. 1998). In other words, the spectacular gains in biomass and carbon in the above average fertility sites should not be taken to mean that they are more rapidly restored in terms of biodiversity, but only that they gain biomass more quickly. More study is required to determine whether the greater total diversity in poor areas persists over time as the canopy closes overhead.

In this chapter we find in addition that households with above average soils (*terra roxa estruturada eutrófica*, or alfisols) are consistently more able to hold onto their land than households who lack these soils, and that they are more likely to have a diverse land use strategy than those with poor soils. In short, the proportion of the land characterized by high-fertility soils is a major component in explaining the land use trajectory of households in a colonization front that we have tracked for the past twenty-eight years. Current and past models of land use have only rarely paid much attention to the difference that soils can make in shaping the land use trajectory of households, and in the resilience of the landscape to a range of land uses.

Study Area and Methods

This chapter begins with an overview of the results of our studies in five regions of the Amazon (see map 7.1). The five study areas represent char-

acteristic differences in soil fertility and a range of land uses typical of the region. One of these areas, Altamira, is characterized by above average soils because of the presence of patches of alfisols—soils with above average pH and nutrients and excellent texture. The other four areas are more typical of the 75 percent of the Amazon that is characterized by oxisols and ultisols, with well-drained but low pH and low levels of nutrients (Cochrane and Sanchez 1982; Nicholaides et al. 1983). Ponta de Pedras in Marajó Island, located in the estuary, is composed of upland oxisols and floodplain alluvial soils. Igarapé-Açu in the Bragantina region is characterized by both nutrient-poor spodosols and oxisols. Tomé-Açu, south of Igarapé-Açu, represents a mosaic of oxisols and ultisols. Yapú, in the Colombian Vaupés, is composed of patches of spodosols and oxisols. Three of the areas are colonization regions at various degrees of development: Altamira is a colonization front that opened up in 1971, whereas Tomé-Açu was settled by a Japanese population in the 1930s, and Bragantina was settled in the early part of the twentieth century. Marajó is the home of *caboclos*, whereas Yapú is home to Tukanoan Native American populations. In these study areas we find slash-and-burn cultivation as well as plantation agriculture and mechanized agriculture. Lengths of fallows vary in these communities. The two indigenous areas leave their land in longer fallow than do the three colonization areas, and the proportion of land prepared from secondary forests increases with length of settlement as the stock of mature forest declines over time.

At each site, soil samples were collected with a dutch bipartite soil auger at 20-centimeter intervals down to a depth of 1 meter. Soil color was determined by use of Munsell color charts, and chemical and textural analyses were carried out by the soil laboratories of the Cocoa Research Center (CEPLAC) and the Brazilian Agropastoral Research Center for the Humid Tropics (EMBRAPA/CPATU) in Belém, Pará, Brazil. Soil samples were taken in association with vegetation inventories in secondary succession areas at various stages of regrowth, and in adjacent mature forests as a control over initial forest and soil conditions.

In association with the vegetation and soil sampling, household interviews were carried out to examine the age/gender composition of households, their history of land use, and the changing trajectory of economic activity on the property. At the more fertile site, a study was carried out by the first author in 1972–74 that involved long-term residence in the area, a detailed household and demographic survey of 136 households, and soil sampling (Moran 1975 and 1981). Secondary succession was the focus of studies in 1991–93. A more detailed household-level study began in 1997,

Map 7.1. Study areas

with 402 of the interviewed households included in our final sample, and use of aerial photos and Landsat satellite data covering every three years since the beginning of settlement (Brondízio et al., chapter 5 in this volume; McCracken et al. 1998; McCracken et al. 1999; McCracken et al., chapter 6 in this volume). The overlay of the property grid on this satellite time-series permits extraction of land cover at both the property level and the landscape level, facilitating aggregation and disaggregation of land cover and its association with land use trajectories verified by household-level interviews.

Soils and Succession

Studies of secondary succession have been steadily increasing (Alves et al. 1997; Brown and Lugo 1990; Dantas 1988; Mausel et al. 1993; Moran et al. 1994; Nepstad et al. 1991; Saldarriaga 1985; Uhl 1987), but rarely have their findings been connected to differences in soil fertility or texture (among the exceptions are Moran and Brondízio 1998; Moran et al. 2000; Tucker et al. 1998). Ecologists have long noted the tendency of plant communities to change through time—a process that is referred to as *succession* (Clements 1916; Luken 1990). The way we use the term in this chapter, "succession" represents a gradient from pioneer species that grow quickly when an opening in the canopy occurs, to the gradual turnover of species as these pioneers are replaced by slower-to-mature forest tree species.

Human populations participate in this process of creation of openings through their land use activities. Much of the work on succession points out that different degrees of disturbance result in differential rates of secondary growth (Uhl et al. 1988), and in cases of very intense pasture use points to impoverishment of the seed bank and to very slow rates of regrowth (Nepstad et al. 1991). Given the poverty of many of the soils of the Amazon, cultivation periods have tended to be short, and successional fallows have played an important role in soil restoration through accumulation of biomass, buildup of organic matter and litter, and reduction in weed species. Among traditional populations, so-called fallows have been actively managed to provide food, fiber, and pharmacologically important plant substances (Denevan and Padoch 1988; Posey and Balée 1989).

Regrowth dynamics are closely correlated to factors such as the way the forest was cut and burnt; the land used in different crops and/or pasture; the length of use; the technology used; the presence or absence of surrounding forest vegetation; the size and shape of the area; the soil's fertility; and the presence or absence of species whose dispersion pattern relies on wind and/or animals that frequent fallows (Howe and Smallwood 1982; Salomão 1994; Uhl 1987; Vieira et al. 1996).

To begin our assessment of differences in soil fertility among our study sites, we constructed a soil fertility index based on the suggestions of Paulo Alvim (1974). The index uses pH, organic matter, phosphorus, potassium, calcium and magnesium, and aluminum. This method for expressing relative soil fertility graphically is useful in understanding the proportions of major elements in tropical soils. The index was prepared for each depth at 20-centimeter intervals, and an average index was prepared across depths. In figure 7.1 we present the soil fertility index developed to illustrate the differences in overall fertility of these sites. Altamira's superior soils can be visually observed in this index, particularly its higher pH, phosphorus,

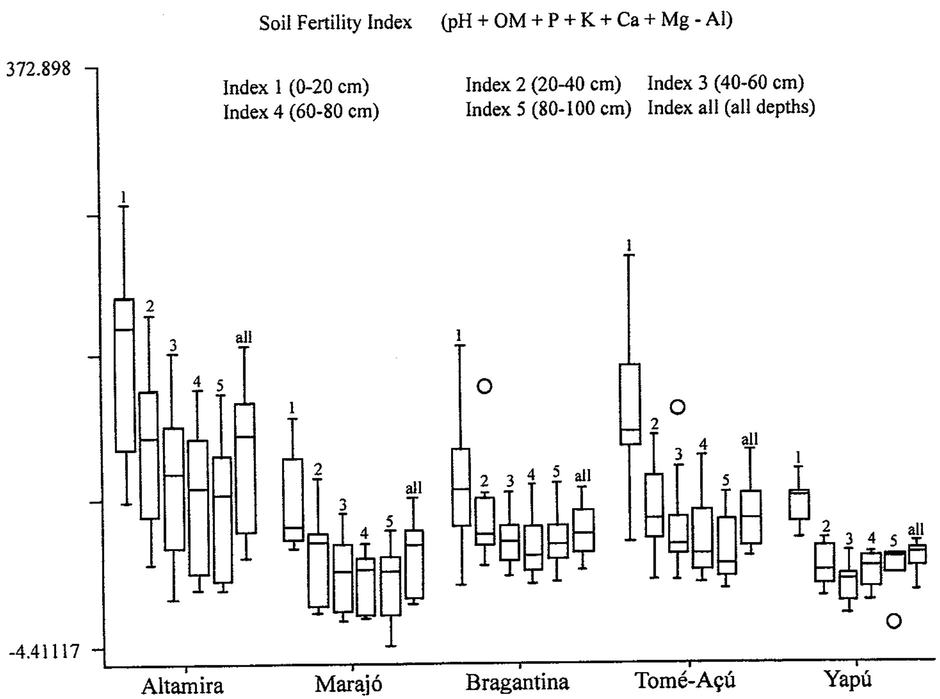

Fig. 7.1. Soil fertility index. The index represents fertility as defined by pH, organic matter, phosphorus, potassium, calcium, and magnesium levels and relative lack of aluminum saturation (based on Alvim 1974).

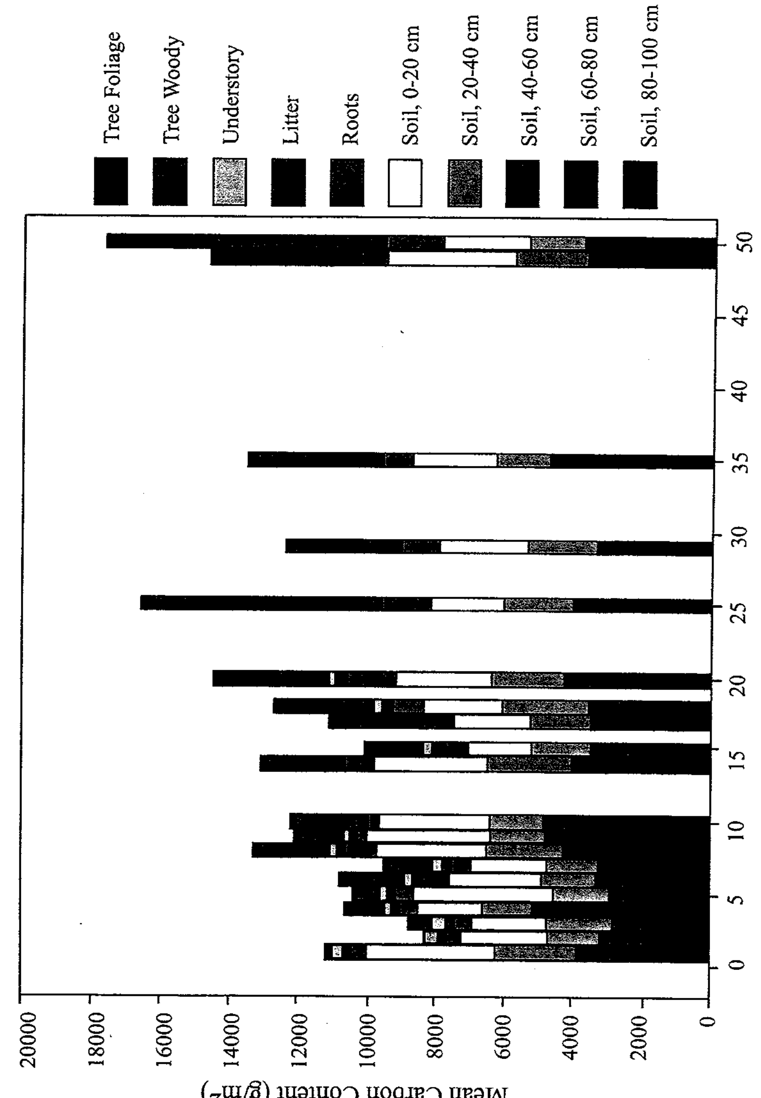

Fig. 7.2. Carbon content in successional forests of eastern Pará, Brazil

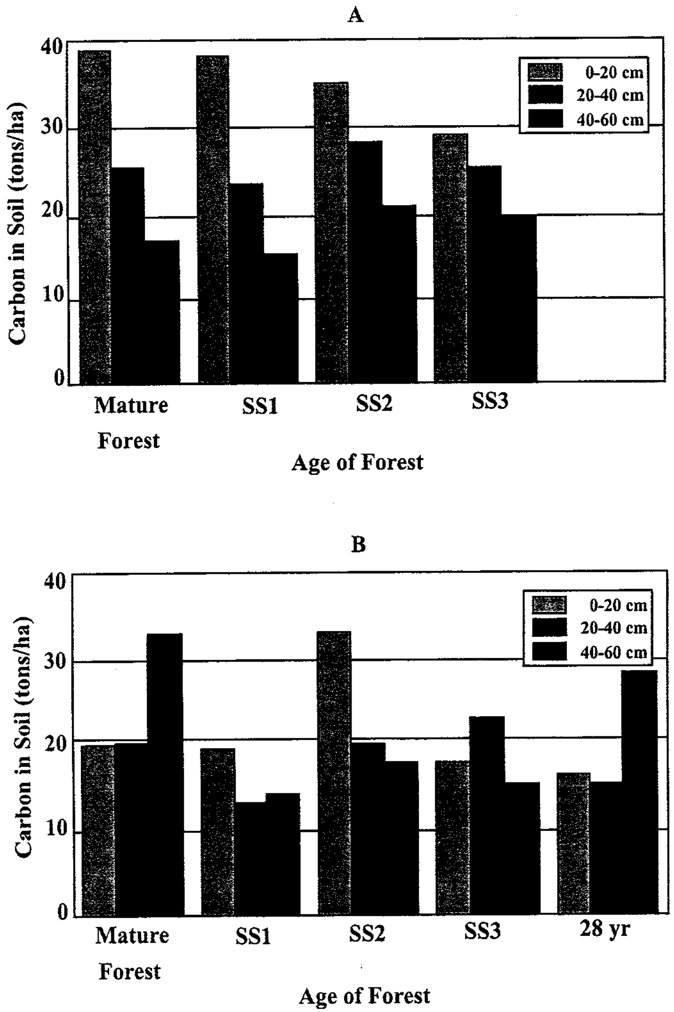

Fig. 7.3. Soil carbon in Altamira (7.3a) and Bragantina (7.3b) sites. Mature and successional forests at three soil depths (0–20, 20–40, 40–60 cm).

calcium and magnesium, and organic matter, and lower aluminum saturation.

Soil fertility proved to be the key element that discriminated among rates of secondary succession when comparing our five study regions. The poorer the soil, the more developed the root biomass component tends to be, as the vegetation searches for nutrients and attempts to capture available substances before they escape from the catchment area. In extremely nutrient-poor areas of the Rio Negro, Herrera and others (1978) have noted that the water entering streams is of nearly distilled water quality. Up to 67 percent of total biomass was below ground in the poorest site studied (see fig. 7.2), whereas the amount of below-ground biomass at the most fertile site was 20 percent. Middling sites fall in between these two extremes. On the more fertile soils, the root biomass is significantly lower, and more of the nutrients are found in the soil rather than primarily in the vegetation itself as is the case in the poor soils. Note the higher amounts of soil carbon in the Altamira site as compared with the Bragantina sites in figure 7.3.

Soil structure and texture, as represented by percentage of fine sand, coarse sand, silt, and clay, were analyzed. Coarse sand and clay are the elements most able to provide discrimination across regions (see fig. 7.4). Altamira soils have low content of fine and coarse sand at all depths (averaging around 10 percent) and clay content above 45 percent at all depths. Although the Yapú region presents a similar textural pattern, it differs in the presence of a spodic B-horizon with low permeability and penetrability. Marajó and Bragantina soils are rather similar in terms of sand and clay content at all depths. In both cases, average fine and coarse sand content are above 25 percent and average clay is below 20 percent at all depths. Tomé-Açu soils have lower content of fine sand (below 25 percent) and higher clay content (30–40 percent) at all depths.

Differences in soil fertility are small but significant. Altamira stands alone in terms of soil fertility, with differences among the four other sites more subtle, as shown in figure 7.5. The average pH above 5 in Altamira contrasts with a pH below 5 in the other regions. However, the pH is lower in Yapú and Marajó than in Bragantina and Tomé-Açu. Yapú has the highest aluminum saturation and the lowest concentrations of calcium and magnesium. This nutrient-poor and acidic profile is reinforced by the low availability of phosphorus. Phosphorus is considered the most limiting nutrient in the Amazon (Cochrane and Sanchez 1982), frequently found only as a trace (less than 1 part per million). Phosphorus is low in all study regions, but it is slightly higher in Altamira. Organic matter did not differentiate among regions.

Analysis of variance shows that soil fertility is associated with differences in rates of regrowth, using height increments as a measure of biomass gains (adj. $r^2 = 0.69$, $p = .05$). Similar regrowth rates between Marajó, Bragantina, Tomé-Açu, and Yapú are consistent with their similar soil endowments. Altamira is the only region with above average rates of regrowth (see fig. 7.6). During the first five years, Altamira fallows are 2

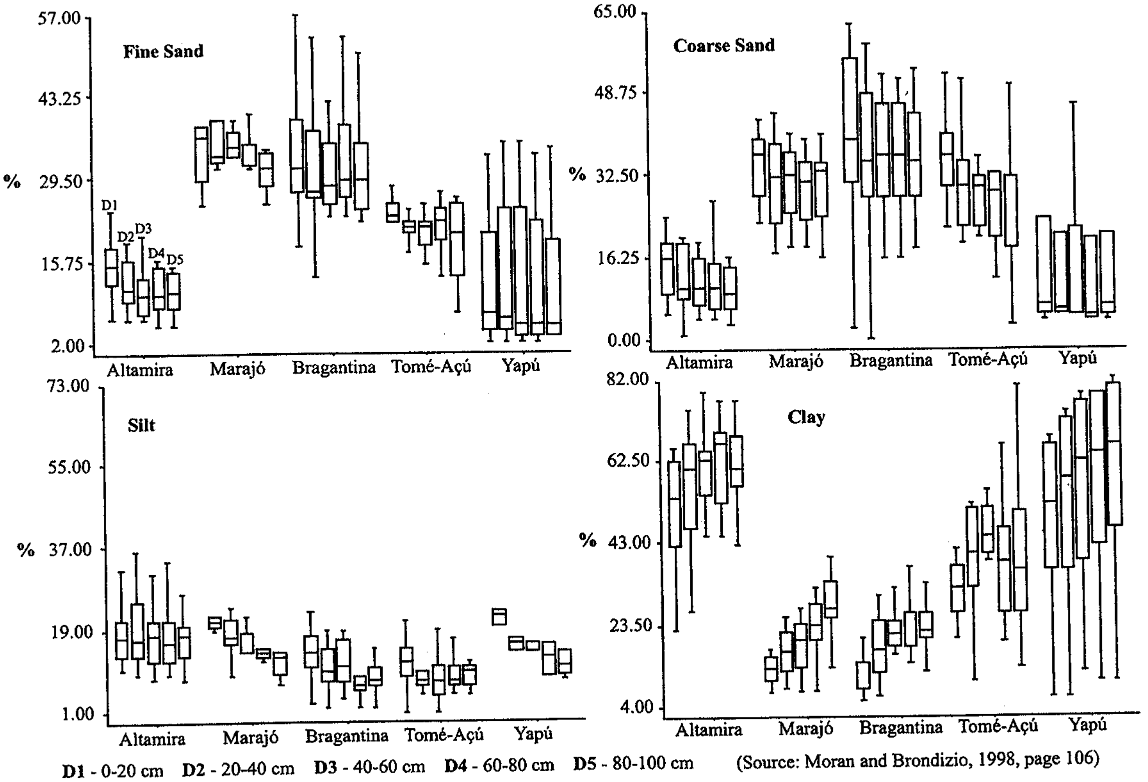

Fig. 7.4. Soil texture by depth (Altamira, Marajó, Bragantina, Tomé-Açú, Yapú)

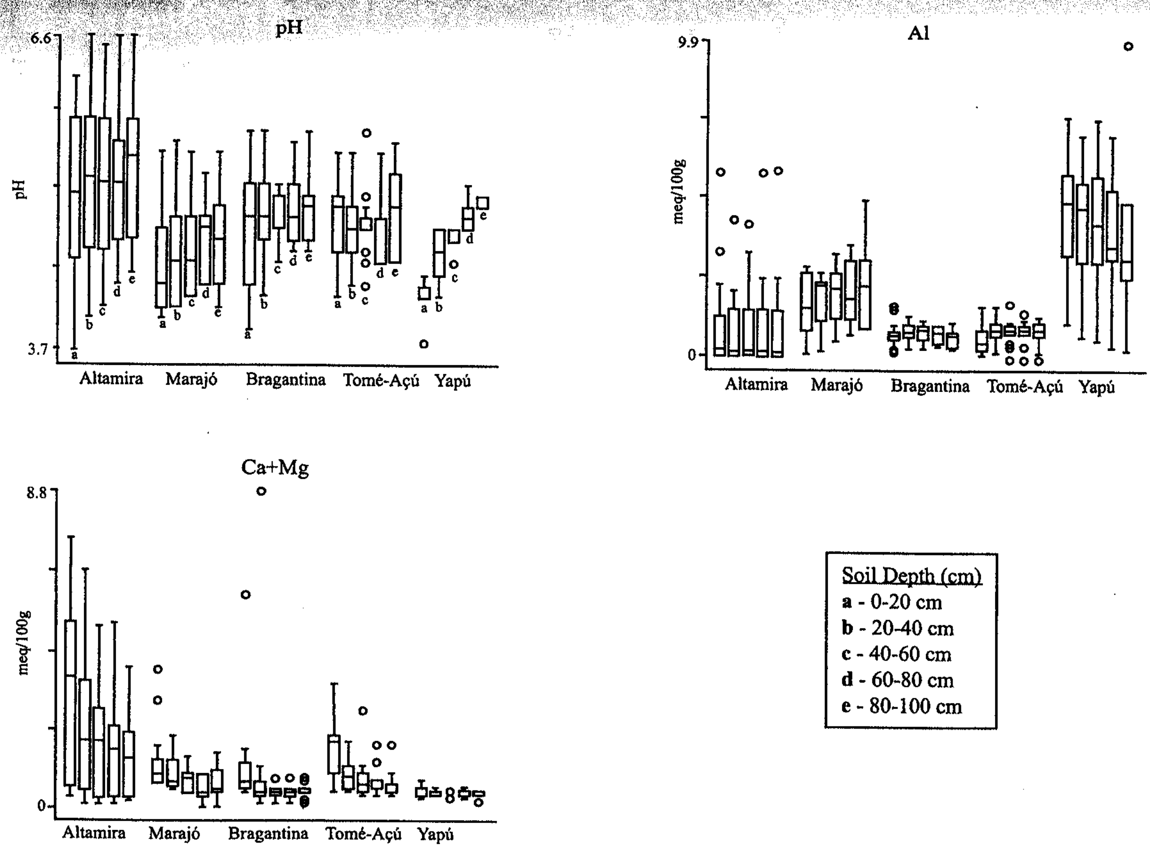

Fig. 7.5. Levels of pH, aluminum, and calcium and magnesium by soil depth at five study regions. *Source:* Moran et al. 2000, 142.

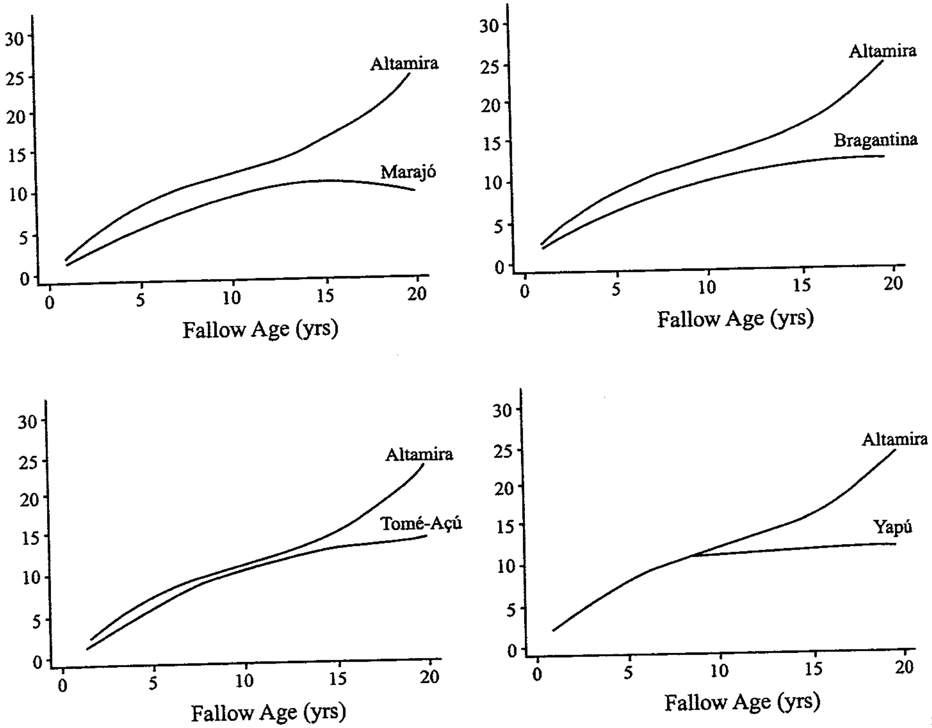

Fig. 7.6. Height increment in secondary succession. *Source:* Moran and Brondízio 1998, 108.

meters higher on average, and 5 meters taller on average by year 15 of succession. When considering maximum tree height, Altamira fallows are three times taller than those in the poor-soil regions. Taking another measure, a 15-year fallow in the poor regions has reached only 17 percent of the tree basal area of the adjacent mature forest, whereas in that same period of time an Altamira fallow will have reached 45 percent of the tree basal area of mature forest (see fig. 7.7 and Tucker et al. 1998).

Land Use in Altamira

Land use is not simply a product of the natural endowments of a place, whether soil, moisture, or temperature. These biophysical endowments interact with individual, household, and community characteristics of the human population that lives in that place. The Altamira site in the Xingu Basin of the Brazilian Amazon will be used in this section to examine the

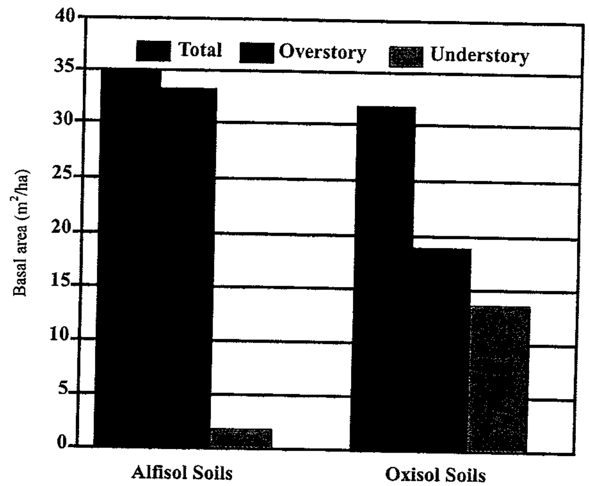

Fig. 7.7. Comparison of basal area on soils of different fertilities. On alfisols, most of the basal area is in the overstory due to greater canopy development, whereas in acid, nutrient-poor oxisols there is a greater contribution from the understory vegetation. *Source:* Tucker et al. 1998.

trajectories of land use through time as they shift with changing social, economic, and demographic processes. The city of Altamira was an old trading post in the rubber trade, and its fortunes rose and fell with the trade. In the 1950s an effort was made to attract colonists from northeast Brazil, mostly from Piauí, who came and settled along streams as far out as 20 kilometers from the city center. With the construction of the Transamazon Highway in 1970, this population and older *caboclo* settlers from earlier rubber eras claimed land along the new highway and legalized their land claims. One of the findings from the first author's original study in the early 1970s was that the *caboclos* used vegetative criteria for selecting soils good for agriculture, and that their criteria were accurate and resulted in higher yields per hectare than the criteria used by the arriving colonists (Moran 1975 and 1981).

Our restudy of the area (see fig. 7.8), using a combination of Landsat time-series digital data and a much larger household survey, supports this early finding. Substantial areas of *terra roxa* are still occupied by the pre-1971 colonization cohort. Only 6.25 percent of the pre-1971 cohort had no *terra roxa* on their current properties, whereas 62.5 percent of that cohort had half of their land with *terra roxa*, and 25 percent had more

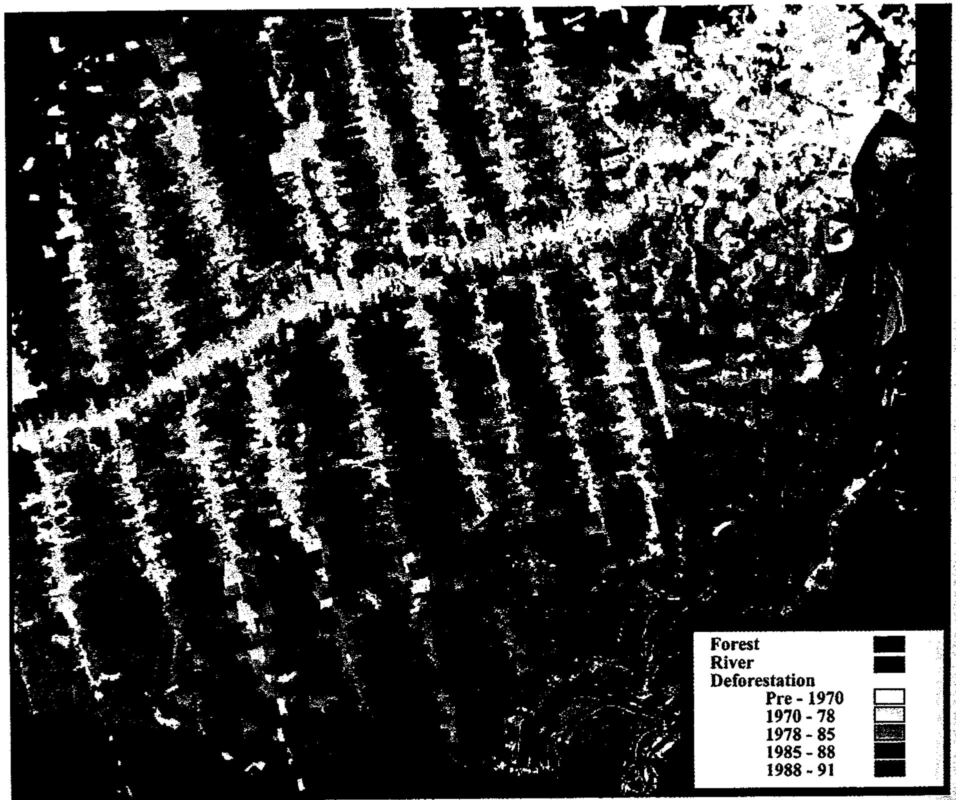

Fig. 7.8. Deforestation along the Transamazon Highway, Altamira, 1970–91, showing the path of deforestation. Note the significance of the 1970–78 cohort.

than half of their land with *terra roxa*. In contrast, 38.82 percent of the migrants that came between 1971 and 1975 (the largest single cohort in the study area) did not select land with *terra roxa*, 21.18 percent had lots with up to half of the area in *terra roxa*, and 40 percent were fortunate to find lots with more than half of the area in *terra roxa*. Nearly 63 to 73 percent of settlers after 1975 were unable to locate themselves on lots with *terra roxa* (see table 7.1). This suggests that land turnover is much less in lots having *terra roxa*, as post-1975 settlers should have been able to have more *terra roxa* properties if they had been for sale. Figure 7.9 illustrates the spatial distribution of *terra roxa*, using the distribution of properties planted in cocoa as a proxy for the presence of *terra roxa* and its areal extent. While some farmers planted cocoa in the 1970s on non–*terra roxa* soils, this tree crop did poorly on those soils, and today the presence of

Table 7.1. Percentage choosing *terra roxa* by cohort

% *terra roxa*	Before 1971	1971–75	1976–80	1981–85	After 1985	Total
None	6.25[a]	38.82	62.69	62.12	72.62	59.45
1–25	6.25	10.59	14.93	19.70	13.10	13.68
26–50	62.50	10.59	7.46	12.12	1.79	8.71
51–75	18.75	7.06	4.48	3.03	5.95	5.97
76–99	6.25	12.94	2.99	1.52	5.36	5.97
100	0.00	20.00	7.46	1.52	1.19	6.22
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: Survey in Altamira 1998, N = 402 households.
a. Cohort is based on the year of arrival in the lot.

cocoa is closely associated with *terra roxa*, although it may not perfectly represent its areal extent.

This relationship is further confirmed by verifying how many of the post-1975 settlers obtained new plots vis-à-vis purchased land from early settlers. Seventy-six to 90 percent of the properties of settlers coming after 1975 had previous owners, as compared with less than 20 percent of the settlers before 1975. Given the small proportions of *terra roxa* in post-1975 cohorts, it appears that the land that is on the land market is differentially non–*terra roxa* properties. In short, land turnover is not random, but is a product of farmer decisions as to their initial choice of soil quality

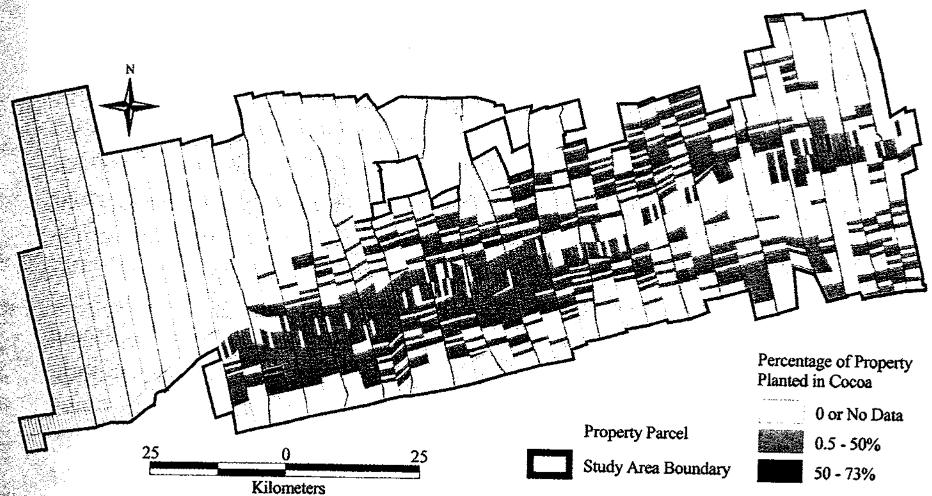

Fig. 7.9. Altamira: percentage of property planted in cocoa

and subsequent production outcomes related in part, but not totally, to their soil endowments. Those who arrived early and selected *terra roxa* plots have been able to perform well enough to be able to stay on their farm holdings more frequently than those who came later or who failed to select the more favorable soils. In an earlier paper (Moran 1987), the first author found in another colonization area characterized by fertile soils (Tucumã) that farmers with poor soils experienced yields ranging from 432 to 1,002 kilograms per hectare, whereas farmers with *terra roxa* had yields from 570 to 1,880 kilograms per hectare. Thus, while outstanding management skills permit farmers on even poor soils to raise their production above levels achieved by poor managers on excellent soils, the achievable yields on excellent soils with good management are nearly twice those achievable even by excellent managers on the poor soils. Soil quality and management skill both matter, but the soil endowment caps what is achievable by even superior skills and can make a difference in the ability of households to hold onto their land when problems arise in the conditions for production.

There are no significant differences among cohorts arriving in Altamira in the proportion of owners who acquire more than one property. For all arriving cohorts, 64 to 70 percent have only a single 100-hectare property, and 30 to 36 percent have more than one property. In the proximity of Altamira there is evidence of land consolidation undertaken by Altamira ranchers, bankers, and merchants who acquire several properties near the city. This process has particularly taken off since the currency was stabilized in 1994. We have also observed a significant increase in deforestation in the mid-1990s, a process that Eduardo Brondízio et al. discuss in chapter 5.

As students of change, we expected more dramatic changes than we found in the composition of the population since 1973. Those who arrived early but with little capital did well at the outset of settlement in the early 1970s (1975) and are still doing considerably better today in terms of accumulated durable goods than many other settlers who arrived later with more capital (see fig. 7.10). This was an unexpected finding that reflects the difference between the aggregate analysis of all households and our observations of particular families, where the wealth of some individuals gave the impression that later arriving households were doing much better than earlier cohorts that arrived with little capital at the beginning of settlement of the region. As was the case in 1972–74 when the first author began studies in the region, the total population today has only 21 to 26 percent of households with prior business experience and

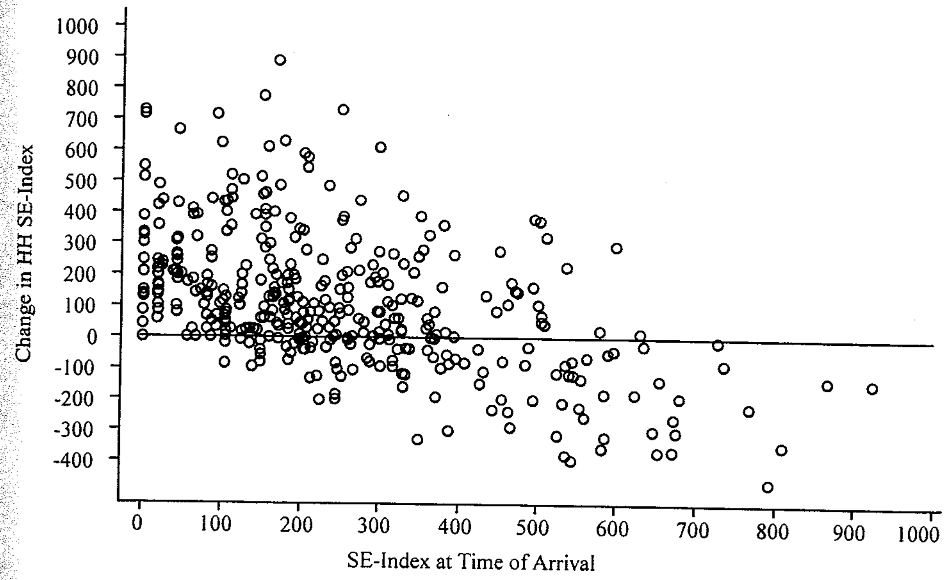

Fig. 7.10. Change in index of household goods/durables: arrival to present. Indicators of socioeconomic conditions at the time of arrival on the farm lot and at present are based on the weighted sum of responses of households to whether they had eighteen household goods (stove, refrigerator, clock, sewing machine, television, stereo, chain saw, rifle, and various types of vehicles). Each item was weighted by the percent of households that did not have the item to provide an overall indicator that reflects the relative importance of each of these items.

farm property before coming to the frontier, and only 21 percent who had urban property before coming to the frontier. Most intriguing, and important to note, is the fact that having capital before coming to the frontier did not assure settlers of obtaining the best land in the area. Early arrival was more predictive of having *terra roxa* than initial capital. However, having some capital and arriving early is most predictive of obtaining *terra roxa*—although the amounts of initial capital of the earliest cohorts were modest indeed (approximately U.S.$500).

Nearly 30 percent of the cohort that arrived in the heyday of new settlement in Altamira (1972–75) were of urban origin with little agricultural experience, in contrast to the agriculturally experienced pre-1971 cohort of *caboclos* in the area, and the 1975 to 1985 cohorts of nonsubsidized settlers characteristic of so-called spontaneously settled frontiers. However, our survey suggests that the cohort settling after 1985 has more than 20 percent of its members with little agricultural experience and more

Table 7.2. Crops and *terra roxa*

Terra roxa (%)	Pasture (%)	Cocoa and Sugarcane (%)	Other (%)	Total
None	85.18	2.68	12.15	100.00
1–25	82.99	7.50	9.51	100.00
26–50	78.79	15.42	5.79	100.00
51–75	53.81	32.09	14.10	100.00
76–99	55.02	35.56	9.43	100.00
100	47.74	43.00	9.26	100.00

Source: Survey in Altamira 1998, N = 402 households.

capital than other cohorts. How well they perform in this frontier remains to be seen, although the results to date are not encouraging.

If any frontier offers choice of crop it is the Altamira region, with its patchwork of alfisols and oxisols, well-drained and well-structured soils, a strong dry season of four months, and abundant but well-distributed precipitation. Nevertheless, here as elsewhere in the Amazon, the predominant choice is pasture (Hecht et al. 1988). If we group the farm properties by percentage of *terra roxa* we observe a modest decline in the percent of land in pasture where more than 50 percent of the land is in *terra roxa*, and there is a larger area in cocoa and sugarcane (table 7.2). There is a marked decline in land use for pasture from land with no *terra roxa* (85.18 percent) to land entirely with *terra roxa* (47.74 percent) (table 7.2). In contrast, in the classes with more than 50 percent of *terra roxa*, the proportion of the land in cocoa and sugarcane rises significantly. Black-pepper, acerola, coffee, corn, beans, and other staple and cash crops are grown, but overall they account for less than 14 percent of the cleared land throughout the twenty-five years we have monitored the study area of Altamira.

One strong reason for favoring pasture over other land uses is the favorable treatment it continues to receive from banks for credit. More than half (55 percent) of the population seeks out formal credit (table 7.3). In 37 percent of the cases the credit obtained is applied to pasture-related operations and 20 percent is applied to perennial crops, primarily cocoa or sugarcane. The remaining credit is used for a variety of agricultural activities (table 7.4). The amount of credit provided for cattle and pasture tends to be larger than for crops, and length of time to payment of the loan longer and thus less risky to the borrower given the wild oscillation of the Brazilian economy. Cattle is also a particularly liquid asset that permits quick conversion to cash to meet needs of households: it can walk itself to

market (thereby overcoming the limitations of poor roads in the region), and the pastureland makes it more attractive to buyers with cash than intensively cultivated cropland.

Our current study of the Altamira region is particularly focused on trying to disentangle period effects from cohort effects, and particularly the role of the developmental cycle of domestic groups (in other words, their changing age and gender composition through time) on the population's land use trajectories. Although our survey data were still being collected at the very end of 1998, and only recently was data entering completed, preliminary results suggest that indeed, as households age and begin to lose members, their land use strategy switches from annual crops to pasture, and then to a mixture of pasture, cocoa, and sugarcane. The choice of cocoa and sugarcane is, moreover, constrained by the soil quality present on the property. We are currently working on separating these demographic determinants from the role of capital in these households, since it is also possible that as households age, they accumulate capital,

Table 7.3. Crops and credit

Crops	No Credit (%)	Credit Once (%)	More than Once (%)	Total (%)
Pasture	80.73	77.40	72.99	77.62
Cocoa and Sugarcane	7.43	12.65	16.96	11.60
Other[a]	11.84	9.95	10.05	10.78
Total	100.00	100.00	100.00	100.00
Observations	179	122	101	402
Percent	44.5	30.4	25.1	100.0

Source: Survey in Altamira 1998, N = 402 households.
a. "Other" includes areas in annual crops, manioc, garden horticulture, coffee, black-pepper, fruit trees, planted trees, and other minor crops.

Table 7.4. Use of credit

Activity	Number of Cases	Percentage
Agriculture	120	32.09
Agriculture/cattle ranching	23	6.15
Cattle ranching	139	37.17
Perennials	75	20.05
Equipment	17	4.55
Total acts of credit	374	100.00

Source: Survey in Altamira 1998, N = 402 households.

and they are able to make a switch from staple crops to a more diversified strategy.

Trajectories of Land Use

The above discussion helps us begin to develop trajectories of land use that take into account the combined effect of soils, deforestation trajectory, successional forest dynamics, and crop choices. It has been suggested by classic studies of the frontier that the early settlers are replaced by later-arriving settlers with more capital and know-how, and that land consolidation proceeds inexorably in a capitalist frontier (Turner 1920). Our analysis, like those of many other colleagues, finds that indeed there is steady land turnover, but we find that turnover is not random but differentially more frequent on properties with fewer soil endowments. We find that arriving early in the frontier was most predictive of locating the best soils in the area, and that once these were located, most households have been able to hold onto their land and to accumulate substantial amounts of durable goods over time. In contrast, settlers who arrive late are less frequently able to obtain the best soils in the region, despite larger amounts of initial capital, and their turnover rate is much higher; they accumulate fewer durable goods; and they even experience substantial net losses in capital from their Amazonian adventure.

Our analysis confirms the work of many other Amazonian scholars who have documented the dominance of pasture as a land use strategy without regard for cohort or period effects (Hecht et al. 1988; Walker et al. 2000). Remarkably, pasture developers even disregard the soil endowments present, except for a modest reduction in pasture areal extent in properties characterized by more than 50 percent of *terra roxa*, where one finds an increase in cocoa and sugarcane area. In our view, allocation of alfisols to pasture represents misuse of one of the scarcest resources in the Amazon.

The Altamira region, unlike other regions of the Amazon, has had a relatively peaceful history of settlement. Early settlement was driven by geopolitical goals and political economic policies that transferred production of staples like rice, corn, and beans from the southernmost Brazilian states to the north region. The region has had a gradual shift to a more diverse set of land uses: pasture, cocoa, sugarcane, black-pepper, and staple crops. Mahogany is beginning to be planted in cocoa groves as a diversification strategy and can be expected to benefit landowners who have the best soils in the area. In the past, and in the future, it makes a

difference what soils a property has. The early-arriving *caboclos* and experienced small farmers with modest capital have had very positive results over time because of their choice of soil and subsequent stewardship. The value of these properties will continue to increase because they represent relatively scarce high-quality areas in the Amazon.

Public policy should take an interest to ensure that small farmers, who have historically been the group most able to intensify production and make diverse use of their land and labor, continue to benefit from their intensive use of high-quality soil resources—rather than favor policies that lead to the *capinização* or "savannization" of even the most fertile soils of the Amazon to provide convenient tax writeoffs for absentee owners. Land use diversification on the most fertile soils of the Amazon should continue to grow even more than it has to date, if a balance between use and conservation of resources in this rich realm of nature is to be achieved.

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Figure 7.9

Altamira: Percentage of Property Planted in Cocoa