Could old colonization zones in the urbanizing and industrializing countries of Latin America become sites for a tropical forest transition in which reforestation becomes more prevalent than deforestation? We try to answer this question through a case study of land-use change and migration since 1985 in a long-settled region of the Ecuadorian Amazon. Data from remote sensing analyses, household surveys, and land-use maps of individual farms reveal two disparate patterns of reforestation in the region, one on peripheral lands far from roads and the other on lands close to roads. The former pattern characterizes most places experiencing a forest transition; the latter pattern does not. Roadside reforestation has occurred in part because Amerindian smallholders have abandoned cattle ranching in order to practice short-cycle shifting cultivation of crops for expanding urban and export markets. This example suggests that tropical forest transitions may differ from earlier temperate forest transitions in that reforestation does not signify land abandonment. Even as they come to rely more completely on nonfarm sources of income, smallholders in developing countries continue to manage their land, reforesting when it eliminates expenses or promises new, near-term streams of income. Key Words: deforestation, forest transition, reforestation, tropical rain forests.

Rapid rates of tropical deforestation during the late 1980s prompted one observer to call the ‘80s a “decade of destruction” for tropical forests (Cowell 1990). A later assessment of changes in the extent of tropical forests between 1980 and 1990 confirmed this grim conclusion. The Food and Agricultural Organization of the United Nations (FAO) calculated that tropical rain forests declined by .9 percent per annum between 1980 and 1990 (FAO 1993). The FAO’s most recent forest resource assessment showed declines of almost the same magnitude for the 1990s, but with one significant difference: some regions in the tropics—primarily in Asia—showed signs of significant reforestation (FAO 2001). This latest turn of events recalls earlier historical episodes during the nineteenth and early twentieth centuries during which the now affluent, temperate zone countries experienced a turnaround in their forest cover trends. Deforestation ceased and variable amounts of reforestation occurred when European and North American societies began to industrialize and urbanize. Analysts call this change “the forest transition” (Mather and Needle 1998).

Recent analyses of land-cover changes in long-settled regions of Brazil (Moran, Brondizio, and Mausel 1994), Mexico (Klooster 2000), Malaysia (Brookfield 1994), and the Philippines (Preston 1998a) report fields reverting to forests. Thus, a similar turnaround may conceivably be beginning in countries undergoing urbanization and industrialization in the tropics. Because spreading secondary forests would slow climate change by sequestering carbon and expand beleaguered habitats sheltering concentrations of biodiversity, the advent of a tropical forest transition would be welcome news to many.

The concept of “the forest transition” belongs to a set of beguiling ideas that promises to deliver us from our environmental ills through economic growth. In this respect, it resembles arguments about ecological modernization and environmental Kuznets curves that anticipate environmental improvements when, with continued industrialization, people replace old technologies with newer, cleaner technologies (Barbier 1997; Mol and Sonnenfeld 2000). These arguments have an almost seductive quality, because they envisage a solution for environmental problems within the prevailing growth-oriented, economic paradigm. It would be easy to accept them without close scrutiny and err in the process. For this reason, arguments about forest transitions, environmental Kuznets curves, and ecological modernization require searching empirical examination before they can be regarded as credible. We hope to contribute to this empirical endeavor through a detailed case study that assesses the likelihood of a forest transition in an old colonization zone in the Ecuadorian Amazon.
Our analysis begins with descriptions of two approaches to understanding social and ecological changes in former frontier regions: a hollow frontier thesis, in which agrarian class transformations produce little change in forest cover; and a forest transition thesis, in which out-migration by smallholders induces a major increase in forest cover. After brief descriptions of the research setting and our research methods, we assess the theses in light of our empirical findings. This discussion suggests the forms that tropical forest transitions might take.

**Landscape Change along Former Frontiers: Theoretical Approaches**

**The Hollow Frontier Thesis**

The most historically prevalent understanding of social processes on Latin American frontiers postulates little change in forest cover as frontiers age. Referred to as the “colono [colonist] system,” this idea describes a recurring sequence of events on Latin American frontiers. The sequence begins when poor peasants blaze trails, make small clearings, and plant subsistence crops in an expanse of forest. After several years of cultivation, crop yields on the new lands decline, and peasants turn the land over to wealthy landlords, who convert it to pasture. The peasants then move farther into the forest and clear a new patch of land for subsistence crops. The departure of the peasants from the first region creates what demographers call a “hollow” frontier, a place that depopulates when pioneers move away and cattle pastures replace subsistence plots (James 1959, 491–92). Fields become pastures; forest cover either remains unchanged or continues to decline as ranchers expand the size of their pastures.

This sequence of events characterized a wide variety of frontiers in Latin America between 1920 and 1980. Studies of frontiers in Brazil (Foweraker 1981), Bolivia (Stearman 1985), Colombia (Ortiz 1984), Venezuela (Watters 1971), Central America (Jones 1989), and southern Mexico (O’Brien 1999) all report a similar sequence of events. Some recent reports (Brown et al. 1994) show a similar pattern, but with several notable differences. As above, a period of land consolidation follows the initial period of settlement. However, in these instances peasants do not move farther into the forest; instead, they move to cities, fueling the urbanization of the region (Browder and Godfrey 1997). The newly landless then become available for new colonization efforts that contribute to further deforestation, or become seasonal laborers for large-scale agricultural or extractive enterprises (Assies 1997).

The colono system presumes that cattle ranching organizes the use of land along most neotropical frontiers. This assumption is empirically well founded. For example, pasture constituted 93 percent of the agricultural land in the Brazilian Amazon in 1995 (IBGE 2001). When other agricultural production systems predominate in a place, the hollow frontier may take a somewhat different form. Soybean producers with large landholdings, mechanized operations, and few workers have cleared large areas of tropical rain forest in Santa Cruz, Bolivia and Mato Grosso, Brazil (Kaimowitz and Smith 2001). These places never contain many people. Whether or not smallholders depart from a frontier agricultural district, leaving it empty, or never reside in a district, forest cover does not increase as the fields in these districts grow older. It may continue to decline if the demand for livestock products generated by growing urban populations pushes commodity prices to high levels (Faminow 1998). Land concentration and deforestation, both of which occur along hollow frontiers, have characterized large areas of the Brazilian Amazon in recent years (Moran et al. 2000).

**The Forest Transition Thesis**

The idea of a forest transition provides a summary description of the historical relationship between economic development and forest cover as it has unfolded over the past two centuries in Europe and North America (Walker 1993). During early periods of commercial expansion in the eighteenth and nineteenth centuries in the United States, settlers and entrepreneurs cleared land rapidly. Later, as urban industrial enterprises became more numerous, smallholders began to abandon farms and move to cities. In many instances, the abandoned lands reverted to forests. Land abandonment occurred selectively. Remote lands with rugged topography reverted to forest, while the most capable lands remained in production, favored by superior location, more fertile soils, or a less forbidding climate (Mather and Needle 1998). Secondary forests grew up on the abandoned lands, and net reforestation began to characterize places. While forest historians have seen this sequence of events unfold in many places, there is nothing inevitable about it; the history of forests in North America conforms to this model, but the history of forests in the Mediterranean basin does not (Mather 1990). This suggestive but inconclusive historical record leaves open the possibility that a forest transition could occur in the tropics as societies urbanize and industrialize.

With allowances for local variations, the agricultural histories of old colonization zones in the neotropics have
followed an identifiable path that could lead to a forest transition. For varying periods of time, the first settlers in a region earn their livelihoods from accumulated natural resources. They take commercially valuable timber from old growth forests and farm without fertilizers, relying on the fertility of pre-existing soil resources for bountiful harvests. Eventually, pest problems increase, and a succession of crops depletes the fertility of the soil, precipitating a *barbecho* (weed) crisis (Thiele 1993). Under these circumstances, some smallholders abandon, sell, or lose their lands, while others fallow more land and turn their energies to other pursuits. The newly idled lands sometimes revert to forest.

Studies of old colonization zones in eastern Amazonia report extensive areas of degraded fields and pastures in the process of doing so (Uhl, Buschbacher, and Serrão 1988; Nepstad, Uhl, and Serrão 1991; Brondizio et al. 1999). Smallholders in western Amazonia have created extensive secondary forests while engaged in shifting cultivation (Smith et al. 1999). Although the authors of these studies note the increasing incidence of secondary forests, they do not see them as harbingers of a forest transition in Amazonia. Rather, they see secondary forests as historical byproducts of extensive deforestation, occurring only when and where primary forests have been destroyed. This perspective on secondary forests, while undoubtedly correct, does not address the possibility that the recent increases in secondary forests may be part of a long-term change in forest cover trends that some observers would call a forest transition.

Any credible argument of this sort must begin by acknowledging the substantive differences between historical processes of urbanization and industrialization in Western Europe and North America during the nineteenth and twentieth centuries and comparable processes in Latin America and Southeast Asia today. Streams of rural-to-urban migration have characterized both sets of nations, but industrialization has generated fewer manufacturing jobs and more poorly paid service sector jobs in Latin America and Asia than it did in Europe and North America. These differences, in turn, imply differences between tropical and temperate zone forest transitions. Given the more precarious nature of urban livelihoods and the increased ease of transportation between urban and rural areas in contemporary developing countries compared with developed countries a century ago, rural-urban migrants might be less willing than were their European and North American predecessors to abandon agricultural lands outright. Contemporary smallholders may try to pursue economic activities in both rural and urban settings, following “a road of many returns” between rural landholdings and urban labor markets, each of which provides small streams of income (Waters 1997). These livelihoods would allow for the recovery of some forests, because smallholders reduce their pressure on the land when they begin to earn significant amounts of nonfarm income. At the same time that they allow some lands to reforest, smallholders may intensify their use of other tracts of land if income-earning opportunities present themselves (Bebbington 1997, 191).

Out of this ensemble of activities, a forest transition emerges. Unlike the case with earlier forest transitions, in modern ones people rarely allow fields to revert to forest without having an income-generating plan, such as fallowing the land for future cash-cropping or enriching a regenerating forest by planting commercially valuable trees. David Preston has found evidence for this mix of livelihood and landscape change in diverse locales, in rural Java (Preston 1989), interior Luzon (Preston 1998a), and highland Ecuador (Preston 1990). In Ecuador, in a pattern consistent with temperate forest transitions, peripheral lands have reforested first. Taken together, these strands of evidence suggest that the idea of a tropical forest transition merits serious attention.

These two theses about forest cover in former frontier regions differ most dramatically in their assessments of the impacts of out-migration on land-use trends. In the hollow-frontier thesis, the loss of agricultural labor with out-migration does not induce land abandonment and reforestation, because the wealthy landowners who accumulate land use so little labor in raising cattle or cultivating soybeans. In the forest-transition thesis, out-migration triggers spontaneous reforestation, because no one remains to work the land. We use these theses as heuristic tools for interpreting reforestation, because no one remains to work the land. The case study should clarify what form, if any, a tropical forest transition might take.

### The Setting: An Old Colonization Zone in the Ecuadorian Amazon

The World Bank categorizes Ecuador as a “lower middle income developing country” with a per capita annual income of U.S.$1520 in 1998 (World Bank 2001). The country earns most of its foreign exchange from exports of oil, bananas, and shrimp. One recent econometric analysis places Ecuador, in the early 1990s, just above the dividing line beyond which additional increments in per capita income should produce declines in the deforestation rate and the beginning of a forest transition (Rock 1996, 115).
Unfortunately, economic growth and increments in personal income have been difficult to achieve in recent years. Since the onset of the debt crisis in the early 1980s and the decline in oil prices during the mid-1980s, the economy has either contracted or grown very slowly. Poverty levels increased throughout the 1980s and again after 1995. A series of partially implemented structural adjustment programs adopted in response to fiscal crises has reduced the services that the state provides to rural residents. The central government has cut the amount of credit available to farmers, and it no longer makes credit available to smallholders at concessionary rates. Improvements in rural transportation infrastructure occur at a slow pace, if at all. Rural residents are twice as likely as urban residents to have incomes below the poverty line (Schodt 1997). This differential in incomes explains, in large part, the continuing urbanization of the population. The proportion of the population residing in urban areas has increased from 47 percent in 1980 to 62 percent in 2000 (World Bank 2001).

The region under study lies in the Chiguaza River basin in the province of Morona Santiago (see Figure 1), just to the east of the Ecuadorian Andes. It features a broad plain with deeply cut rivers that flow eastward into

![Figure 1. The Chiguaza region of Ecuador.](image)
left bank tributaries of the Amazon. The rivers run fast, so, rather than providing channels of communication as they do in the lower Amazon basin, they represent obstacles to communication until someone builds a bridge to cross them. The mean elevation of the region ranges from 1100 meters in the east to 1500 meters in the west. Rainfall averages 4000 mm per year with little seasonality. The predominant soils are hydromorphic, which are acidic and have low cation exchange capacities. The pH of soil samples from the region ranges from 4.9 to 5.5, which makes the soils of marginal utility for crop cultivation (Moran and Brondizio 1998, 105). Aluminium toxicity and the absence of phosphorus further limit the agricultural potential of the soils. Their poor quality has convinced planners in the Ministry of Agriculture that the region should remain forested (Ministerio de Agricultura 1980).

Widespread settlement and deforestation began during the 1960s, when the local regional development agency announced that they would build a penetration road north through the region. Amerindians (the Shuar), mestizo (mixed-race) colonists, and wealthy investors laid claim to land in the region and began to clear it at rapid rates. By 1980, a populist frontier had emerged. The Shuar had title to approximately 50 percent of the land in the region; colonists controlled 40 percent of the land, and the owners of two large haciendas raised cattle on the remaining land. By 1983, these groups had cleared almost half of the arable land in the region (Rudel with Horowitz 1993, 109–32). The land generated incomes for landholders through cattle ranching, cultivation of a citrus fruit, naranjilla (Solanum quitoense), and the logging of commercially valuable species of trees such as laurel (Cordia alliodora).

During the 1990s, access to roads remained uneven within the region. Some farmers had roads running through their land, while others had to walk six or seven hours from their farms to get to the nearest road. Although the north-south road between Macas and Puyo connected the region to urban markets in Ecuador’s Coast and Sierra, access to markets for agricultural goods remained tenuous. For most of the 1980s and 1990s, the bridges along this road could not bear the weight of a truck loaded with agricultural produce, so merchants had to transfer products at considerable expense from trucks on one side of a river to trucks on the other side of the river in order to get products to urban markets.

Beginning in the late 1980s, the pest infestations typical of old colonization zones made the large-scale cultivation of naranjilla impossible in the Chiguaza region. At the same time, loans for cattle ranching became less available. Under these circumstances, large numbers of people left their homesteads to find work in urban places. Many of the emigrants went no further than urban centers in the Amazon region, such as Macas or Puyo. With economies structured around the provision of public services, these places did not offer much economic opportunity during a period of fiscal austerity (Ryder and Brown 2000). Other migrants ventured further afield, looking for work in Quito, Spain, or the United States.

Why look for a forest transition in this setting? The poverty of the larger society should reduce the likelihood of a forest transition by limiting off-farm economic opportunities, but the region’s deteriorating natural resource base and out-migration would increase the likelihood of a forest transition. In these respects, the region is probably typical of many old colonization zones in economically distressed developing countries. Thus, an investigation of the dynamics that govern land-cover change in this setting may help us answer questions about the likelihood of forest transitions in a broad range of tropical regions.

**Methods**

To investigate land-use change in the Chiguaza region, we relied on a strategy of methodological triangulation, bringing different types of data to bear on the question of interest (Denzin 1970, 471–75). We used four types of data to ascertain the existence of a forest transition in the Chiguaza region: satellite images of the region taken in 1987 and 1997, household surveys conducted in 1986 and 1997, maps of land use drawn by farmers in 1997, and key informant interviews conducted on numerous occasions since 1980. In the rest of this article, we present remote sensing analyses of the satellite data, multivariate analyses of the household survey data, and a geographic information systems (GIS) analysis of the farm maps in an effort to characterize the changing patterns of land use in the region.

We performed the remote sensing analysis on two thematic mapper (TM) images with maximum resolution of 30 square meters. The images were shot ten years apart, in September 1987 and September 1997. Prior to processing the data, the images were geographically rectified and centered on a common Universal Transverse Mercator projection using a 1:1,000,000 topographical map of Ecuador. As part of this process, we used a geographical positioning system to measure the coordinates of series of prominent points, such as road intersections, in the images. We then carried out supervised classifications of both images. As the first step in this process, we identified ten to twelve ground-truthed training sites for each
of the major land uses in the region and analyzed the spectral qualities of these sites to see if they possessed unique spectral signatures. In addition to the expected distinctions between water, rock, bare ground, and urban land uses, we found distinct spectral signatures for pastures, gardens, secondary forests, and primary forests. We then used these spectral signatures to classify the rest of the 1987 and 1997 images. We carried out the analyses on fourteen areas of interest in the Chiguaza region. Site-specific accuracy assessments were 85 percent for the 1987 image and 87 percent for the 1997 image. We then used the results from the two classifications to carry out an analysis of changes in land uses during the 1987–1997 decade. The units of analysis in the remote sensing analyses are communities. We used a cadastral map of Shuar villages to identify boundaries between communities and established the boundaries between areas of interest in the remote sensing analysis so that they coincided with political boundaries between communities (Federación de Centros Shuar 1985). Because the Shuar and the colonists live in separate communities, each area of interest identifies an ethnically homogenous community.

The survey data come from two household surveys, conducted eleven years apart. The first survey involved heads of 62 households from two matched Shuar and colonist communities in the region. These data are useful largely because they establish a benchmark for measuring recent trends in the region. The second survey, conducted in 1997, involved interviews with the heads of 274 households who reside or have resided in the region. This sample contains data on 72 Shuar households from two communities and 202 mestizo households from five communities. We conducted interviews in peoples’ homes and asked them questions about their livelihoods, families, migration histories, and land-use patterns. The interviews averaged more than an hour in length. Because the Shuar and colonists have shared a sometimes fractious history in Morona Santiago, we used separate teams of researchers to carry out the interviews among each ethnic group. We analyzed the patterns in these data with particular attention to the emergence of secondary forests on farms and factors that might explain the appearance of regrowth on some but not all farms.

The final set of data comes from a GIS analysis, using Arcview 3.2, of maps that farmers drew of their own lands indicating the major types of vegetation. The maps indicate both the extent and the location of secondary forests on farms. They helped us characterize trajectories of land-use change on particular types of farms in the region. We supplemented the GIS, survey, and remote sensing data with extensive key informant interviewing in the Chiguaza region during a dozen visits over the past two decades.

**Results**

Forest transition theory implies that reforestation begins on less fertile soils in less favored locations, usually away from roads. Table 1 displays remote sensing data that bear on this expectation: it compares land-use changes in communities with and without roads. Primary forests continued to decline and pastures continued to

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<tbody>
<tr>
<td>Primary forest</td>
<td>Roads</td>
<td>31.9</td>
<td>25.6</td>
</tr>
<tr>
<td></td>
<td>No roads</td>
<td>57.5</td>
<td>49.9</td>
</tr>
<tr>
<td>Secondary forest</td>
<td>Roads</td>
<td>6.9</td>
<td>15.5</td>
</tr>
<tr>
<td></td>
<td>No roads</td>
<td>11.4</td>
<td>9.2</td>
</tr>
<tr>
<td>Pasture</td>
<td>Roads</td>
<td>27.7</td>
<td>43.7</td>
</tr>
<tr>
<td></td>
<td>No roads</td>
<td>14.3</td>
<td>27.6</td>
</tr>
<tr>
<td>Crops/garden</td>
<td>Roads</td>
<td>24.5</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td>No roads</td>
<td>11.2</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Sources: Remote sensing images, 1987 and 1997. Note: Summaries of land-cover data for twelve communities in the Chiguaza region. Seven of the communities have roads; five do not. The reported categories sum to between 85 and 95 percent of the land in a community. Bare ground, rock, water, urban land, and unclassifiable land covers make up the rest of the land area.
increase in extent in both roadside and roadless communities, while secondary forests—contrary to the expectations of forest transition theory—emerged at a faster pace in communities along the roads. The precipitous decline in the extent of land in gardens between 1987 and 1997 stems from the pest-induced abandonment of naranjilla cultivation in the early 1990s. To reduce the costs of transporting naranjilla to markets, people cultivated it close to roads, so the collapse of the naranjilla trade primarily affected land use in communities with roads.

Figures 2, 3, and 4 provide a more visual understanding of the patterns of land-use change in the region. Figure 2 portrays land-use changes between 1987 and 1997 in thirteen areas of interest in the Chiguaza region. Mestizo communities in the western portion of the region have the most extensive tracts of pasture, while Shuar centros (villages) in the eastern part of the region contain the largest blocks of primary forest. A close inspection of the location of secondary forest (the light green area in Figure 2) and the road in the western parts of the region indicates that the extent of secondary forest increases with distance from the road.

Figure 3 presents remote sensing images for the Shuar centro of Tsemainmain, located along the main north-south road through the region. A comparison of the 1987 (a) and 1997 (b) land-use patterns reveals two obvious changes. First, the secondary forest (light green) landscape is much more common in 1997 than in 1987: the centro experienced a net increase in forest cover during the decade. Second, the horticultural land uses—coffee (Coffea sp.), cacao (Theobroma cacao), naranjilla, and manioc (Manihot esculenta)—are concentrated closer to the road in 1997 than they were in 1987. This change in the location of horticultural land uses stems from the growth of cash-cropping for urban and export markets.

Figure 4 portrays land uses in the mestizo community of Sinai in 1987 (a) and 1997 (b). A comparison of the two images reveals a couple of patterns. First, horticultural land uses declined dramatically over the period be-
between 1987 and 1997, especially in the northern and western portions of the community, away from the transportation corridor created by the north-south road that runs just to the east of the village. The declines depicted here represent the widespread abandonment of the naranjilla crop. Second, continued declines in the extent of primary forest and increases in the amount of pasture can be seen in the western parts of the community. This trend reflects the continued economic appeal of cattle ranching among mestizos.

Figure 5 charts the changing likelihood of regrowth as distance from the road increases, and it demonstrates that ethnicity mediates the regrowth-remoteness relationship. The curves in the figure summarize bivariate scatterplots of the amount of secondary forest on a landholding and the distance of the landholding from the road.
Figure 4. Land-cover change from (a) 1987 to (b) 1997 in a mestizo community, Sinai.

The patterns in these data accord with those from the remote sensing analyses. The probability of reforestation takes a U-shaped form, with the highest probability occurring on lands closest to the road, followed by a lower probability, and then a higher probability again as the distance from the road exceeds more than three kilometers.

Reforestation occurs close to the roads when landowners—most frequently Shuar—decide to fallow lands before using them again to cultivate cash crops. GIS analyses of land use on thirty mestizo farms and the survey data from mestizo households show a small increase in the probability of reforestation as distance from the road increases. Field inspections and farm-specific maps of secondary forests indicate that mestizo smallholders often allow sloped land in gullies to revert to forests on farms far from the road: fourteen of twenty-eight secondary forests inspected on foot were in or along the edge of gullies. Smallholders’ preference for reforesting gullies stems from the practice, prevalent in the region, of teth-
ering cows in pastures rather than allowing them to graze in fenced pastures. Tethering cattle on sloped land increases the risks that the cows will strangle themselves in the rope, so landowners throughout the region have been allowing pastures in this type of terrain to revert to forest at the same time that landowners between one and three kilometers from the road have continued to clear other land for pasture. Soil samples of lands reverting to forest and adjacent lands remaining in pasture show no significant differences in fertility. The lands reverting to forest in roadside corridors exceed in extent the lands reverting to forest in the interior (see Table 1).8

Table 2 displays survey and census data for a mestizo community (Sinai) and a Shuar community (Uunt Chiwias). The trends in these data suggest some of the social and economic forces driving land-use changes in the region. The population declines in the mestizo community and increases in the Shuar community reflect dramatic differences in migration patterns between the two communities. Out-migration from mestizo communities increased sharply in the late 1980s when pest problems made large-scale naranjilla cultivation unprofitable. Between 1987 and 1997 more than 140 persons, mostly young adults, left Sinai (Bates 2000). In contrast, only 20 to 30 persons left Uunt Chiwias during the same time period. These contrasting migration patterns account for the diverging trends in household size: the departure of young mestizo adults produced sharp declines in the size of mestizo households, while Shuar households increased slightly in size.

The departure of numerous people from the mestizo community accords with the hollow frontier thesis about old colonization zones. However, landholdings in the community did not consolidate into larger units. Instead, they declined in size as parents subdivided their landholdings in order to provide the younger generation with some land. In addition, several larger farms broke up in the early 1990s, when their owners sold them to pursue more lucrative opportunities outside the region. With this change and the subdivision of other properties, the Gini coefficient—an index of land concentration—remained low and virtually unchanged in the mestizo community during the decade. In the Shuar community of Uunt Chiwias, the index increased somewhat, although to still-low levels, when some households subdivided their farms while others did not. Even though

Table 2. Changing Attributes of a Mestizo Community (Sinai) and a Shuar Community (Uunt Chiwias), 1986–1997

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<tr>
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<tbody>
<tr>
<td>Population</td>
<td>Mestizo</td>
<td>519</td>
<td>432</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>246</td>
<td>393</td>
</tr>
<tr>
<td>Household size (mean)</td>
<td>Mestizo</td>
<td>6.8</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>5.9</td>
<td>6.3</td>
</tr>
<tr>
<td>Landholdings (mean—in hectares)</td>
<td>Mestizo</td>
<td>61</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>63</td>
<td>53</td>
</tr>
<tr>
<td>Gini coefficient—land concentration</td>
<td>Mestizo</td>
<td>0.48</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>0.36</td>
<td>0.49</td>
</tr>
<tr>
<td>Pasture (percentage of all land)</td>
<td>Mestizo</td>
<td>63</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td>Head of cattle (mean per farm)</td>
<td>Mestizo</td>
<td>23.3</td>
<td>15.6</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>5.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Bank loans (percentage of farms)</td>
<td>Mestizo</td>
<td>90</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Shuar</td>
<td>25</td>
<td>21</td>
</tr>
</tbody>
</table>

Sources: Surveys and censuses conducted in Sinai and Uunt Chiwias in 1986 and 1997.
landholdings did not consolidate into larger properties during the decade, the landless class of households grew in size, as young people formed households without having any lands to work. Between 1986 and 1997, the proportion of landless households in Sinai increased from 20 percent to 42 percent of all households. A demographic process, rather than—as the hollow frontier thesis would assert—the actions of large landowners, accounts for the increasing levels of inequality between households in mestizo communities.

With the collapse of the naranjilla sector, mestizos began to rely on the sale of cattle and timber for income. Cattle prices remained relatively stable throughout the 1990s, so mestizos continued to convert forest into pasture at the same time that they allowed particularly remote pastures or those costly to manage to revert to forest. Mestizos continued to plant pastures, despite the loss of concessionary credit for cattle ranching in the mid-1980s. Prior to that date, the government’s agricultural development bank adjusted interest rates once a year, which, given rising rates of inflation, amounted to making loans at negative rates of interest. After the mid-1980s, loan rates fluctuated with the inflation rate, so the real costs of loans to borrowers increased (Sierra 1991; Banco Central del Ecuador 1994). High rates of cattle mortality in the rough, recently created pastures of the Chiguaza region also put some borrowers in arrears with the banks. Although few mestizos lost their lands to the bank, the prospect of doing so persuaded some of them to stop taking out loans, and, as a consequence, they reduced the size of their herds.

The most dramatic declines in herd size occurred among the Shuar. They, too, found it more difficult to obtain credit as the managers of the credit program of the Federación de Centros Shuar (Federation of Shuar Villages) reduced the volume of their lending in response to higher-than-expected default rates among borrowers (Picard 1996). The economic pressures to produce livelihoods from smaller tracts of land, coupled with Shuar cultural preferences for shifting cultivation as opposed to cattle ranching, contributed to a change from land-extensive cattle ranching to land-intensive cash-cropping during the decade (Rudel, Bates, and Machingiuashi 2001). The proportion of Shuar lands in pasture declined, while the proportion in secondary forests increased.

Multivariate analyses of variations from farm to farm in the extent of secondary forests offer a more precise picture of the forces behind their creation. Table 3 presents two analyses of variations in regrowth on farms in the Chiguaza region. Panel 1 models the probability that a farm will or will not contain secondary forest. The equation contains an efficient set of predictors, given that it correctly classifies almost 84 percent of the farms and that the pseudo R2 explains more than 23 percent of the variance. Panel 2 regresses a series of variables on the amount of forest regrowth occurring on farms. The equation does not suffer from the problems that compromise the value of regression analyses. There is little collinearity, and the condition index only reaches 6.8 with all of the variables in the equation. The residuals are normally distributed.

The findings in Panel 1 indicate that regrowth occurs on farms that engage in the cash cropping of naranjilla and cacao, but does not occur on farms that derive most of their income from cattle-ranching and on Shuar farms far from roads. The findings on variations in the extent of forest regrowth in Panel 2 add more detail to the profile of farms with secondary forests. The farms of large households and households that have abandoned the cultivation of several crops contain more secondary forest than do the farms of small households and households that have not abandoned the cultivation of a crop. With

### Table 3. Multivariate Analyses of Reforestation in the Chiquaza Region during the 1960s

<table>
<thead>
<tr>
<th>Model</th>
<th>Equation</th>
<th>R2</th>
<th>significance</th>
<th>Cases correctly classified</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Logistic Regression: The Probability of Reforestation on a Farm: Household and Agricultural Predictors</td>
<td>[-1.4 + .64 \text{Naranjilla Land} + 1.1 \text{Cacao} - 4.1 \text{Cattle Income} - .10 \text{Ethnicity \times Distance from Road}]</td>
<td>.23</td>
<td>.05</td>
<td>.839</td>
</tr>
<tr>
<td>2. Regression: The Extent of Forest Regrowth: Household and Agricultural Predictors</td>
<td>[.39 + .10 \text{Farm Size} + .06 \text{Household Size} + .20 # \text{of Abandoned Crops} - .56 \text{Cattle Income} - .03 \text{Ethnicity \times Distance from the Road}]</td>
<td>.23</td>
<td>.05</td>
<td>.244</td>
</tr>
</tbody>
</table>

Source: 1997 household survey of mestizo and Shuar smallholders in the Chiguaza region.

* **p < .001, ***p < .01, *p < .05. The numbers associated with each variable are B coefficients; the numbers immediately below them are the standard errors of the B coefficients.*
abundant supplies of family labor, large households tend to rely for income on the cultivation of several labor-intensive cash crops such as coffee. In their attempts to capitalize on changing market opportunities, they regularly abandon some crops, introduce new crops, and follow a significant portion of their lands, so secondary forests and a history of abandoning cultivars goes together. Here, as in Panel 2, income from cattle-ranching and distance from the road among the Shuar makes regrowth less likely.

Table 4 reports the reasons that landowners with secondary forests offered for why they had allowed some fields to revert to forest. Concerns with the continuing productivity of agriculture dominate the list. Smallholders fallow their lands, thereby creating secondary forests, in order to restore the fertility of the soil for future cultivation. Smallholders abandon pasture lands without cattle and naranjilla groves infested with pests because these lands no longer produce a profit for them. Labor migration from mestizo communities, either by landowners or their young, does not appear to cause reforestation. Similarly, few people cited the future economic payoff from restocking their lands with commercially valuable tree species as a reason for reforestation.

The salience of concerns about continued agricultural productivity in smallholders’ rationales for reforestation suggests that variations between households in agricultural production processes may explain the patterns of forest regrowth. The willingness of young Shuar in the Chiguaza region to remain in their villages of origin makes it possible for their elders to cultivate cash crops. In this sense, the lack of out-migration among young Shuar has contributed to the emergence of secondary forests on their families’ lands, because young Shuar provide an inexpensive pool of labor for their parents during the labor-intensive phases of the growing season. The presence of adult children on the farm also increases the subsistence demands on the land and the pressures for agricultural intensification. Under these circumstances, Shuar smallholders have the means and the rationale, as their participation in the cattle economy declines, to build an alternative livelihood around the cash-cropping of cultivars that they have raised in their gardens for generations. To build an ecological basis for their renewed commitment to shifting cultivation, the Shuar have allowed pasture to revert to secondary forest, especially in areas close to roads, where cash-cropping is most profitable.

In contrast, the departure of large numbers of young people from mestizo households has had little impact on mestizo land use. Contrary to the expectations of the forest transition thesis, the departure of young people has not led to an increase in land abandonment. As in other Andean regions (Preston 1998b), the absence of a land-use effect from emigration stems from the labor-saving nature of cattle-ranching. Aside from pulling the cattle into fresh pasture twice a day, cattle-ranching on established farms does not require much labor. When male heads of household leave the village to look for work, women and older children begin to “change the cattle.” The recent opening of two daycare centers in the mestizo village of Sinai has made it easier for women to assume more responsibility for the care of cattle and the maintenance of pastures.

Did the collapse of the naranjilla economy precipitate the reforestation of the Chiguaza region? It clearly precipitated land-use changes, but the changes did not always result in reforestation, and they varied by ethnic group and distance from the road. Colonists tended to farm naranjilla farther from the road, and, while they allowed some of their old naranjilla fields to revert to forest, they converted most of these lands into pasture. In contrast, the Shuar, with their lack of enthusiasm for cattle-ranching, allowed secondary growth to envelope their old naranjilla fields.

Table 4. Reasons for Reforesting Land: Percentage of Shuar and Mestizo Landowners with Secondary Forests

<table>
<thead>
<tr>
<th>Reason</th>
<th>All Households</th>
<th>Shuar Households</th>
<th>Mestizo Households</th>
<th>Significance of Shuar/Mestizo Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restore soil fertility</td>
<td>67.8%</td>
<td>82.3%</td>
<td>57.5%</td>
<td>.001</td>
</tr>
<tr>
<td>Fields too far from road</td>
<td>8.1%</td>
<td>3.2%</td>
<td>11.5%</td>
<td>.068</td>
</tr>
<tr>
<td>Labor migration by owner</td>
<td>2.7%</td>
<td>0.0%</td>
<td>4.6%</td>
<td>.088</td>
</tr>
<tr>
<td>Lack of labor on farm</td>
<td>2.0%</td>
<td>0.0%</td>
<td>3.4%</td>
<td>.142</td>
</tr>
<tr>
<td>Failure of naranjilla crop</td>
<td>11.4%</td>
<td>1.6%</td>
<td>18.4%</td>
<td>.001</td>
</tr>
<tr>
<td>Lack of cattle</td>
<td>15.4%</td>
<td>19.4%</td>
<td>12.6%</td>
<td>.267</td>
</tr>
<tr>
<td>Value of trees planted</td>
<td>7.4%</td>
<td>9.7%</td>
<td>5.7%</td>
<td>.369</td>
</tr>
<tr>
<td>N of cases</td>
<td>149</td>
<td>62</td>
<td>87</td>
<td>—</td>
</tr>
</tbody>
</table>

Source: 1997 household survey.
Livelihoods, Hollow Frontiers, and Forest Transitions

The recent history of people and the land in the Chiguaza region conforms to the hollow frontier thesis in one important respect: large numbers of mestizos from smallholder households have left the area, but their exodus has not been accompanied by a consolidation of landholdings in the region. While the Chiguaza region does contain two large cattle ranches run by absentee landowners, the owners have made no recent attempts to expand their holdings. They staked out claims to these lands during the late 1960s at the same time as Shuar and mestizo smallholders established their farms. The large landowners continued to convert forests into pastures on their ranches at a rapid pace during the 1980s and 1990s. By the late 1980s, some mestizos had begun to assemble mid-sized properties of over 150 hectares in extent, but in the economic downturn that followed, the owners of these properties sold off a portion of these landholdings and turned their attention towards more lucrative, off-farm economic opportunities outside the region. In this respect, the Chiguaza region lacks one of the essential features of a hollow frontier: an aggressive landholding upper class intent on acquiring more land.

Has a forest transition occurred in the Chiguaza region? The answer has to be equivocal. In purely quantitative terms, it would appear to be yes, in a limited way. All of the communities in the region experienced massive deforestation between the late 1960s and the mid-1980s. Since 1987, four of the twelve communities—all of them along roads—have experienced net reforestation.

However, assertions about the existence of a tropical forest transition need to be qualified in a couple of ways. First, the idea of a transition implies an enduring change in forest cover trends, and it may well be that the changes described here are transitory. While the shift from cattle ranching to shifting cultivation among the Shuar has led to net increases in forest cover, continued population increases among the Shuar without emigration could eventually lead to reductions in forest cover. Second, the early forest transitions in temperate countries occurred when people left rural places and abandoned marginal agricultural lands. The reforestation of Chiguaza’s remote and sloped lands fits this pattern, but the insignificant role played by out-migration in this process departs from it. Interior reforestation resembles the forest transition pattern in part; roadside reforestation clearly does not.

The two types of reforestation in Chiguaza have analogs in other regions. For example, Bebbington (1997) describes two trajectories of human ecological change in the Ecuadorian Andes, both of which are visible in the Chiguaza region. One involves out-migration and the reduced human pressure on the land implicit in interior reforestation; the other involves intensifying land use with additional labor and allowing once-productive lands to recuperate through long fallow cycles (Bebbington 1997, 191). The latter pattern could involve some roadside reforestation. It recalls the widespread association, outlined by Netting (1993), between productive smallholder agriculture, energy efficiency, and sustainable land-use patterns. This type of agriculture could play an integral part in tropical forest transitions because, unlike emigrants from places that experienced temperate forest transitions, out-migrants in tropical forest transitions never completely cut their ties to the land. Faced with uncertain prospects in urban labor markets, contemporary out-migrants commute between the city and the country, helping their families maintain agricultural enterprises at the same time that they work in the nonfarm sector. Labor-saving livestock operations may make it easier for smallholders to work part-time in both urban and rural locales. A widely applicable conception of a tropical forest transition should include the roadside reforestation that accompanies intensive smallholder agriculture, as well as the more historically familiar reforestation of interior lands.

Conclusion: Forest Transitions in a Comparative and Historical Perspective

This portrait of an emerging tropical forest transition reflects some place-specific circumstances: it has occurred in a former populist frontier, a place populated by smallholders. Forest transitions along old corporate frontiers created by large soybean producers or mineral companies would take a somewhat different form; trends in commodity prices would play a larger role and variations in migration patterns a lesser role in shaping forest transitions in these places. Along old populist frontiers, the distribution of landholdings, the prevalence of out-migration, and the potential for more extensive agriculture may play important roles in precipitating forest transitions. For example, regional differences in land distribution in coastal Brazil between the highly unequal patterns of Bahia in the north and the more equitable patterns of Santa Catarina in the south could affect the likelihood of a forest transition. The presence of large numbers of landless rural people in the north should provide owners with a ready supply of tenant farmers for vacant lands and should therefore suppress regrowth. The relative absence of landless rural peoples...
in the south should increase the prospects for regrowth (Caruso 1990).

In Mexico, a forest transition may occur sooner in Michoacan, a state that sends large numbers of migrants to the United States (Klooster 2000), than in the Yucatan, a state that sends few such migrants (Sohn, Moran, and Gurr 1999). In both Brazil and Mexico, the likelihood of reforestation in a place increases substantially if labor-saving, income-generating land uses such as cattle-ranching are not an option. Enumeration of these place-specific factors underscores the conjunctural nature of forest transitions and implies that, if they occur, they will take place in an incremental and variable fashion, one small region at a time.

Acknowledgments

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Notes

1. Old colonization zones are defined as those that experienced extensive settlement by colonists from other regions at least two decades prior to the period under study. They feature aged cohorts of original settlers and some soil exhaustion.
2. These figures come from eight soil samples taken from different farms in the region.
3. Populist frontiers have regional economies organized around colonists with small farms; corporate frontiers have regional economies organized around the operations of large oil or mining companies (Browder and Godfrey 1997).
4. Figures 3 and 4 actually contain two categories for pasture, stubble (brown, recently grazed pastures) and green (mature pasture) grasses.
5. We could only reliably distinguish between primary and secondary forests within areas of interest that did not vary by more than four hundred meters in elevation. When the areas of interest incorporated lands at quite different elevations, the spectral signatures of the smaller primary forests at higher elevations began to resemble those of the secondary forests at lower elevations. Because this problem only affected the two westernmost areas of interest in our analysis, we do not think that it biased our overall results.
6. The sites we used to assess the accuracy of the classifications were not training sites for either image. Based on the authors' firsthand knowledge of the area, these sites do not constitute a representative sample of the land-cover classes, so the accuracy assessment, while useful, is not as reliable as it might be.
7. Because we only visited sites with the permission of landowners, the presence of some landowners in a village and the absence of others shaped which secondary forests were visited and which were not. While this choice of sites constitutes a convenience sample, we do not think that it biases our results in an obvious way.
8. The extent of roadside and interior reforestation can be determined from either the remote sensing or the survey data. Both types of data show more reforestation occurring close to the road, but the differences in the extent of the two types of reforestation are more marked in the remote sensing analyses.
9. The proportion of landless households is smaller in the outlying villages.

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