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Contrasting Colonist and Indigenous Impacts on Amazonian Forests

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Abstract

To examine differences in land use and environmental impacts between colonist and indigenous populations in the northern Ecuadorian Amazon, we combined data from household surveys and remotely sensed imagery that was collected from 778 colonist households in 64 colonization sectors, and 499 households from five indigenous groups in 36 communities. Overall, measures of deforestation and forest fragmentation were significantly greater for colonists than indigenous peoples. On average, colonist households had approximately double the area in agriculture and cash crops and 5.5 times the area in pasture as indigenous households. Nevertheless, substantial variation in land-use patterns existed among the five indigenous groups in measures such as cattle ownership and use of hired agricultural labor. These findings support the potential conservation value of indigenous lands while cautioning against uniform policies that homogenize indigenous ethnic groups.

Keywords

Amazon; colonists; deforestation; Ecuador; indigenous peoples; land use

Introduction

Indigenous people and colonists inhabit the Amazon Basin and are widely assumed to differ in their environmental stewardship and conservationist behaviors. Colonists are commonly seen as seeking material gain through extensive land clearing for commercial agriculture, whereas indigenous peoples are thought to possess cultural norms and values that promote conservation and sustainable use of resources (Stocks et al. 2007). We tested the idea that colonist populations in the northern Ecuadorian Amazon have a greater ecological impact on Neotropical forests than do indigenous groups as measured by the amount of area cleared and the spatial arrangement of that clearing (i.e., patterns of habitat fragmentation). Understanding the patterns of land use among colonists and indigenous peoples is crucial to conservation efforts in tropical regions, especially in light of rural population growth, rapid urbanization in frontier regions, and processes of cultural, economic, and social change among Amerindians who control large territories in the Neotropics (Nepstad et al. 2006; Lu 2007).

Relatively few researchers have compared indigenous and colonist land use in the same region**,** although notable exceptions include Garland (1995), Rudel et al. (2002); Hvalkof (2006) and Stocks et al. (2007). In addressing ethnic differences in land use, however, each of these studies has a variety of shortcomings, which we address here. Garland (1995) relied on survey data, whereas Hvalkof (2006) and Stocks et al. (2007) focused solely on remotely sensed data. Our work integrates both types of data, which is crucial because this gives a fuller picture of household decision making and characteristics as factors that help explain environmental outcomes (Vadez et al. 2003). Such linkages between survey and spatial data characterize Rudel et al. (2002) study, but they focused on a test of forest-transition theory rather than an on examining the environmental effects of disparate groups.

We based our findings here on large and representative samples of indigenous peoples and colonists occupying the same forest frontier region in the northern Ecuadorian Amazon (NEA). To compare these populations, we used the results of parallel surveys of over 1270 households and types of land cover identified from Landsat imagery. Our indigenous sample included five ethnic groups: Huaorani, Kichwa, Cofan, Secoya, and Shuar. These groups differ in population size and density, history of contact with outsiders, and linguistic affiliation (Holt et al. 2004).

The NEA study area includes parts of the provinces of Sucumbios, Orellana, Napo, and Pastaza, and borders the Andean foothills to the west and the Colombian and Peruvian Amazons to the north and east. The region's lowland moist tropical forests are among the world's most biodiverse (Pitman et al. 2002). Due to rapid agricultural expansion, urbanization, land-use intensification, and petroleum extraction, Ecuador has had the highest rate of deforestation in South America since 1990 (FAO 2005). Spontaneous migration into the NEA followed the discovery of significant oil reserves by a Texaco-Gulf consortium in 1967. Road construction by oil companies facilitated migration from highland and coastal Ecuador and agricultural colonization (Pichón 1997; Bilsborrow et al. 2004), bringing colonists into the traditional homelands of Amerindian populations.

The total indigenous population of the Ecuadorian Amazon is over 150000 (INEC 2003), which is 30% of the total regional population. Our sample of the Huaorani, Kichwa, Cofan, Secoya, and Shuar encompasses indigenous groups numbering in the tens of thousands to less than a thousand, those who have lived in the NEA for time immemorial to recent migrants from the Southern Ecuadorian Amazon, and those with centuries of sustained contact with outsiders to those who have had contact only within the past 50 years. Holt et al. (2004) provides ethnographic descriptions of the study populations.

Methods

Collection of Survey Data

The survey data we used were collected in 1999 in a survey of colonists carried out among 778 agricultural households in 64 colonization sectors, and in 2001 in a survey of indigenous people carried out among 499 households from 36 communities representing five indigenous groups. Bilsborrow et al. (2004); Pan and Bilsborrow (2005), and Gray et al. (2008) contain additional methodological details on the surveys.

In both the 1999 and 2001 surveys two structured questionnaires were administered to the male and female head in each sampled household. The male head's questionnaire included topics such as land tenure and land use, production and sale of crops and cattle, off-farm employment, and receipt of technical assistance and credit. Informants reported on the land area in various uses. Intercropped areas were divided among constituent uses on the basis of proportional coverage. The female head's questionnaire provided a household roster and information on outmigration from the household and household assets.

To compare colonist and indigenous land use, we used the survey data to derive the total agricultural area managed by each household, area in pasture (almost exclusively for cattle);area in cash crops planted for market (primarily coffee); and area in other crops used for subsistence or sale (e.g., corn, rice, and plantains).

Collection of Spatial Data

A time series of Landsat TM images (1986, 1996, 2002; Path 9/Row 60) was classified with a hybrid supervised-unsupervised classification method (Messina & Walsh 2001). Land-cover classes included forest, pasture, crops, barren, urban, and water. Radiometric correction (Tanre et al. 1990) was applied to make pixel values comparable between images (Song et al. 2001).

Pattern metrics are used to characterize ecological patterns by assessing composition and configuration in categorical maps through the use of indices that describe the spatial and geometric properties of these maps (McGarigal et al. 2002). To understand how changes in land processes in indigenous and colonist areas transform the areal extent and spatial arrangement of forests, we determined landscape pattern for the forest cover class from the remotely sensed images. We used proportion of the landscape covered in primary forest (PLAND), patch density (PD), and largest patch index (LPI) as metrics for landscape composition and patch cohesion index (COHESION) and aggregation index(AI) to measure configuration. Taken together, these metrics balanced explanatory power (Riitters et al 1995), sensitivity to map extent (Saura & Martinez-Millan 2001), and spatial resolution (Cain et al. 1997).

Landsat TM satellite imagery was available for 54 colonization sectors and 16 indigenous territories. We calculated the amount of area covered by primary forest in each territory for two periods—1986–1996 and 1996–2002—and subtracted the forest area of the latter period from that of the former period to obtain the relative difference (Δ) between colonist and indigenous areas. We compared these differences between colonist and indigenous areas with *t* tests.

We calculated the amount of deforestation by determining the difference in forest area at two points in time. The rate of deforestation also describes change in forest area. We calculated yearly deforestation rates for indigenous territories and colonist sectors as follows (Dirzo & Garcia 1992; Ochoa-Gaona & Gonzales-Espinosa 2000):

$$r=1-\left(1-\frac{A_1-A_2}{A_1}\right)^{\frac{1}{t}} \qquad (1)$$

where $A1$ and $A2$ are the forested areas at the start and end, respectively, of the period being evaluated, and t is the number of years within the period.

Results

Land Use

Colonist households managed significantly larger agricultural areas overall, for both pasture and cash crops, but indigenous households managed larger areas in other crops (Table 1). For colonists, total area managed, area in cash crops, and area in pasture were, respectively, 2.1, 1.8, and 5.5 times as large on average as those of indigenous populations. Nevertheless, the area in annual crops was only half (0.48 times) as large. For both colonists and indigenous populations, a majority of the agricultural area was devoted to market-oriented uses, such as pasture and cash crops.

Consistent with the much larger areas in cash crops and pasture, colonist households were more likely to own cattle, use modern agricultural inputs (fertilizer, herbicides or pesticides), sell crops, hire agricultural laborers, and participate in agricultural markets. Indigenous peoples were much farther away from markets, had less access to human capital (such as formal education and the ability to speak Spanish), and were less likely to claim individual tenure over their agricultural lands—all factors likely to limit the extent of agricultural activities (Table 2). Nevertheless, substantial variability existed between indigenous groups. For instance, whereas 1.3% of the Huaorani households surveyed owned cattle, 69.7% of the Secoya did, a rate of cattle ownership higher than the colonists. Cattle ownership among the Secoya was encouraged by Occidental Exploration and Petroleum Company, who operated a concession block in Secoya territory (Valdivia 2005). Although none of the Huaorani had hired agricultural laborers in the previous year, 57.6% of Secoya households did. Kichwa households grew as much cash crops as colonists, with over 82% reporting engagement in this market activity.

Landscape Change

Overall, colonist rates of forest clearance were considerably higher than indigenous rates of clearance (Table 3). For example, between 1986 and 1996 the area in primary forest decreased by 24%in the sample of colonist farms, but decreased by only13% in indigenous territories. The rate of deforestation in indigenous territories was lower in 1996–2002 than in 1986–1996. Nevertheless, the deforestation rate in colonist areas was higher in 1996–2002 and significantly higher than that of the indigenous territories in both periods. Increases in the density of forest patches seen in 1986–1996 and in 1996–2002 reflect forest fragmentation resulting from deforestation. The largest patch-index values indicated that the largest forest patches decreased significantly in size from 1986–1996. Although deforestation of the largest patches slowed in 1996–2002, the largest forest patches in colonist areas were deforested more than in indigenous areas. Measures of patch cohesion index in colonist areas were very low for both time periods, which indicated that although more patches of forest existed, they are not well connected. The low values for the aggregation index pointed to a landscape in which forest patches were disaggregated. The metrics of landscape fragmentation, aggregation and connectedness of primary forest patches all indicated a more fragmented and less connected forest landscape in colonist areas than in indigenous territories.

Discussion

We found that the five indigenous populations studied affected the forest to a much lesser degree than colonists. From 1986 to 2002, indigenous areas exhibited substantially lower rates of deforestation and there was a higher proportion of the landscape covered by primary forest. Furthermore, several measures indicated colonist lands exhibited greater forest fragmentation. The conservation implications of these findings speak to the value of indigenous lands in maintaining forest cover, with the caveat that the categorization of “indigenous people” obfuscates substantial diversity, not just in cultural, historical, and demographic characteristics, but also in terms of land-use patterns.

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Table 1

Mean household land use by ethnicity (SD).*

Measure	Colonists	Indigenous	Kichwa	Shuar	Huaorani	Cofan	Secoya
Total agricultural area (ha)	7.85 (9.24)	3.70 (3.91)	4.18 (3.63)	4.89 (5.57)	1.35 (1.26)	2.30 (2.20)	4.38 (3.18)
Area in cash crops (ha)	2.44 (2.70)	1.31 (1.96)	1.64 (2.13)	2.07 (2.20)	0.06 (0.36)	0.89 (1.32)	0.25 (0.50)
Area in other crops (ha)	0.74 (1.37)	1.56 (1.52)	1.79 (1.70)	1.44 (1.61)	1.28 (1.09)	1.26 (0.94)	1.33 (1.10)
Area in pasture (ha)	4.67 (7.86)	0.84 (2.65)	0.76 (1.81)	1.43 (4.71)	0.00 (0.00)	0–14 (0.50)	2.80 (3.07)
Number of households	778	499	239	99	79	49	33

* Significance of colonist versus indigenous contrasts: all $p < 0.001$.

Table 2

Mean values of selected land-use characteristics of colonist and indigenous populations (percentages except as indicated).

Measure	Colonists	Indigenous	Kichwa	Shuar	Huaorani	Cofan	Secoya
Owned cattle	60.0	28.3	31.8	34.3	1.3	14.3	69.7
Used modern agricultural inputs[a]	33.8	6.3	6.3	12.2	0.0	4.9	4.3
Sold crops[a]	81.6	65.7	82.4	74.7	21.5	55.1	39.4
Hired agricultural laborers[a]	67.4	20.6	18.4	29.3	0.0	22.4	57.6
Travel time to market (minutes)	62.0	229.2	144.6	206.3	446.1	240.8	160.0
Household head spoke Spanish	100.0	89.4	95.8	97.0	67.1	75.5	93.9
Adult men with primary education	68.7	66.4	70.1	81.7	54.8	32.7	70.0
Adult women with primary education	61.9	43.6	48.1	59.3	32.7	14.0	38.9
Individual land ownership[b]	100.0	67.1	78.7	97.0	2.5	36.7	93.9
Household size (mean number)	5.90	6.37	6.56	6.60	6.63	5.62	4.68
Population under age 12	38.4	44.5	44.7	49.6	40.8	42.0	36.6
Total fertility rate[c]	5.0	7.6	-	-	-	-	-

[a] In the previous 12 months.

[b] Land tenure described by the head of household as private rather than land in usufruct or communal tenure.

[c] Mean number of births that a woman would expect to have over her life time on the basis of current fertility of women of different age groups. Not calculated for indigenous subgroups due to small numbers of women of reproductive age.

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Table 3

Rates of forest clearing and comparison of landscape-change metrics for primary forest between colonist sectors and indigenous community territories, 1986–1996 and 1996–2002 (SD).

Metric*	1986–1996			1996–2002		
	colonist	indigenous	p	colonist	indigenous	comparison
Deforestation rate (%/year)	3.93 (1.65)	1.67 (1.41)	<0.001	4.16 (3.51)	0.73 (1.87)	<0.001
Primary forest (%)	−24.42 (7.65)	−13.26 (10.33)	<0.001	−9.47 (5.34)	−2.40 (7.32)	<0.001
Patch density (patches/100 ha)	9.62 (5.21)	3.35 (3.92)	<0.001	0.92 (3.84)	1.89 (2.66)	
Largest patch index (%)	−33.63 (17.43)	−14.37 (13.27)	<0.001	−8.79 (8.63)	−2.37 (7.67)	<0.01
Cohesion (0–100)	−0.09 (0.20)	−0.12 (0.14)		0.08 (0.04)	0.11 (0.09)	<0.001
Aggregation index (0–100)	−1.71 (1.87)	−0.18 (0.34)	<0.001	−1.82 (2.60)	−0.17 (0.37)	<0.05

*This table shows the mean annual rate of deforestation for colonist farms and indigenous territories in the two study samples and measures of change in primary forest as captured by changes in the pattern metrics within the two time periods. Definitions: primary forest, proportion of the landscape covered by primary forest; patch density, indicator of fragmentation measured as the number of primary forest patches per 100 ha; largest patch index, percentage of overall area constituted by the largest forested patch; cohesion, measure of the physical connectedness among patches of primary forest (almost zero when proportion of area covered by primary forest is maximally subdivided and increases up to 100 as forest connectedness increases); aggregation index, measure of spatial aggregation or dispersion of forested patches (zero when the patch types are maximally disaggregated [i.e., there are no adjacent primary forest patches] and 100 when the landscape is contiguous).