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POPULATION, LAND USE AND DEFORESTATION IN THE PAN AMAZON BASIN: A COMPARISON OF BRAZIL, BOLIVIA, COLOMBIA, ECUADOR, PERÚ AND VENEZUELA*

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Abstract. This paper discusses the linkages between population change, land use, and deforestation in the Amazon regions of Brazil, Bolivia, Colombia, Ecuador, Perú, and Venezuela. We begin with a brief discussion of theories of population–environment linkages, and then focus on the case of deforestation in the Pan Amazon. The core of the paper reviews available data on deforestation, population growth, migration and land use in order to see how well land cover change reflects demographic and agricultural change. The data indicate that population dynamics and net migration exhibit to deforestation in some states of the basin but not others. We then discuss other explanatory factors for deforestation, and find a close correspondence between land use and deforestation, which suggests that land use is loosely tied to demographic dynamics and mediates the influence of population on deforestation. We also consider national political economic contexts of Amazon change in the six countries, and find contrasting contexts, which also helps to explain the limited demographic-deforestation correspondence. The paper closes by noting general conclusions based on the data, topics in need of further research and recent policy proposals.

Key words: Amazon, deforestation, land use, migration, population.

1. Introduction

Over the past decade, researchers in numerous scholarly communities have turned their attention to the issues surrounding the sustainability of human occupation and deforestation in tropical forest regions such as the Amazon. Forest loss has many negative biophysical consequences including local soil erosion and runoff into rivers, endemic species loss, loss of environmental services and carbon emissions (e.g., Jordan, 1986; Fearnside, 1990; Gash et al., 1996). No less important are the negative social consequences such as land conflicts, persistent poverty and poor

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health outcomes (e.g., Hall, 1992; Kosinski, 1992). As a result, there has emerged a literature focused on the 'human dimensions' of deforestation (e.g., Turner et al., 1990; 1995).

Pre-eminent in this literature is the role of population as a factor underlying land cover change. However, the empirical findings are mixed (e.g., Kaimowitz and Angelsen, 1998; Geist and Lambin, 2002). In the case of the Amazon, the vertiginous growth of population surely bears some implications for the rapid pace of recent land cover change. That said, closer inspection of theoretical arguments reveals many intervening factors that may alter the population–deforestation link (Wood, 1992; Perz, 2001a).

Identification of the role of population in prompting land cover change is further complicated by the fact that the Amazon is shared by several countries, each with their own distinct histories and political economies. As yet, there are virtually no comparative analyses of population and deforestation for the countries sharing the Amazon basin. This oversight becomes more problematic as the countries sharing the Amazon basin become more integrated by actual or planned road links, air and water-borne commerce, and gas and oil pipelines, all in the broader context of global market integration. In a global context of concern about forest loss in tropical regions such as the Amazon, careful attention must be paid to available data, for they may diverge from common theoretical expectations. Any assessment of the sustainability of ecosystem services and human livelihoods in the Amazon must recognize the importance as well as limitations of the role of demographic expansion for forest loss.

This paper considers the linkages of population and deforestation in the Pan Amazon, by which we mean certain states of Brazil and five Andean countries – Bolivia, Colombia, Ecuador, Perú and Venezuela.[1] First, the paper reviews theoretical perspectives on population–land cover linkages. Recent research and theory highlights the largely indirect influence of population, mediated by intervening mechanisms such as land use practices, as well as contextual differences such as national political–economic structures. Second, we present the most recent available data on deforestation, population growth and composition, migration and land use in the Pan Amazon. The data allow a comparative analysis of the correspondence of population size, growth and net migration, as well as one key intervening factor, land use, with deforestation. This analysis shows limited correspondence between demographic factors and deforestation, and motivates a review of other factors that may alter the population–deforestation link, highlighting contrasts in the political–economic contexts of the six countries considered. The paper concludes by noting some key findings from the data presented, discussing topics related to deforestation that require further research, and reviewing recent policy proposals to mitigate deforestation.

2. Theory on population and the environment: the case of deforestation in the Amazon

Thought on population–environment interactions has many historical antecedents, but neo-Malthusian and Boserupian notions are pre-eminent. Malthus' (1989 [1798]) statement is among the earliest, where he argued that population growth leads to agricultural expansion and ultimately to land degradation and famine. Alternative approaches have emerged since Boserup (1965), who argued that population growth leads to sustainable land use via intensification due to technological changes. Both statements are oversimplifications because of their reliance on historical data from certain societies and specific environments, and because of their lack of attention to cultural and political factors. More recently, Bilsborrow (1987, 2002) articulated the third possibility of a demographic–economic response, via migration from crowded or degraded environments to frontier zones. Since the 1980s, numerous books have been published with discussions of factors that mediate the population–environment link (e.g., Davis and Bernstam, 1991; CCRP, 1993; Martine, 1993; Ness et al., 1993; Arizpe et al., 1994; Mazur, 1994; UN, 1994; Panayotou, 1996; Preston, 1996; MacKellar et al., 1998; Pebley, 1998; Torres and Costa, 2000).New theoretical work also argues that the effect of population on environments depends on many things, including a gamut of cultural and political factors as well as the scale of observation (Gibson et al., 2000; Wood, 2002). Explanations linking population to deforestation have encountered the same difficulties as broader population–environmental research, namely that the relationships are not direct and invariant but are instead mediated by many other factors (e.g., Brown and Pearce, 1994; Turner et al., 1995; Sponsel et al., 1996; Kaimowitz and Angelsen, 1998). This is also the case for the Pan Amazon (e.g., Reis and Guzmán, 1991; Wood, 2002; Moran, 1993; Rudel and Horowitz, 1993; Pichón, 1997; Drigo and Marcoux, 1999; Pfaff, 1999; Wood and Skole, 1998; Perz, 2001a).

During the past few decades, the Pan Amazon has experienced population growth driven by high fertility, declining mortality and in-migration. In many cases, the last of these demographic processes has been particularly intense, spurring rapid population growth in areas exhibiting new land settlement, agricultural expansion and deforestation. That said, the prototypical scenario of in-migration followed by agricultural activities and deforestation is not the only possible course of events (Wood, 1992; Perz, 2002). One alternative, involving largely urban settlement, would not directly lead to deforestation (though it may by indirect means, as by generating demand for local agricultural products). Another possibility is that in-migration ceases but agricultural expansion and deforestation continue, as might occur during periods of economic growth in consolidated areas that still have forest on properties held by migrants from past years. There is evidence that these and other 'alternative' scenarios are proceeding alongside the 'rural in-migration-deforestation' scenario in the Pan Amazon.

The sections that follow present the most recent available data on deforestation, population change, migration and land use in the Pan Amazon. These data allow for a comparative analysis of the importance of population and mediating factors for deforestation in the basin.

3. Deforestation in the Pan Amazon Basin

Table I presents deforestation estimates for the states of Brazil's Legal Amazon from 1978 to 1998. This is a government planning region that encompasses nine states and ∼5 million km^2. The 'Classical' Amazon encompasses the northernmost states with more recent settlement; the 'Other' Amazon comprises states on the southern and eastern fringes of the basin with older settlements. Deforestation estimates in this table are based on analyses of Landsat MSS and TM imagery (INPE, 2001). Deforested area as a percentage of total land area rose from 3% in 1978 to 11% in 1998. Within Brazil's Legal Amazon, deforested land area varies substantially, from pre-frontier states such as Amazonas where it is only 2% to frontier states like Rondônia, where it is 22% and rising rapidly, to old frontiers such as Maranhão, where it is over 30% and rising slowly. Average annual deforestation has changed over time, with a slight decline from the 1980s at 21 560 km^2 per year, or 0.42%, to 17 400 km^2 per year during the 1990s, or 0.34%.

Table II allows for comparative analysis by presenting available deforestation estimates for states in the Andean Amazon countries. In Bolivia, we include the eastern lowlands as defined by Pacheco (1998: 59) to include Santa Cruz, Beni, Pando, and parts of Chiquisaca, La Paz, Cochabamba and Tarija, an area

TABLE I. Deforestation in the Brazilian Amazon, 1978–1998.

State	Percent land area deforested[a]			Average annual percent deforested[b]		Total land area[c]
	1978	1988	1998	1978–1988	1988–1998	
Classical Amazon	1.8	5.4	8.2	0.36	0.28	3 574 239
Acre	1.6	5.8	9.6	0.42	0.38	153 698
Amapá	0.1	0.6	1.4	0.04	0.08	142 359
Amazonas	0.1	1.3	1.8	0.11	0.06	1 567 954
Pará	4.5	10.5	15.1	0.60	0.46	1 246 833
Rondônia	1.8	12.6	22.3	1.08	0.98	238 379
Roraima	0.0	1.2	2.6	0.12	0.14	225 017
Other Amazon	5.8	12.2	17.2	0.64	0.50	1 508 298
Maranhão	19.4	27.6	30.5	0.82	0.30	329 556
Mato Grosso	2.2	7.9	14.6	0.57	0.67	901 421
Tocantins	1.2	7.8	9.5	0.66	0.17	277 322
Legal Amazon	3.0	7.4	10.9	0.44	0.34	5 082 537
Total area deforested[c]	152 200	377 500	551 782	22 530	17 428	

Sources: Deforestation: INPE (2001) analysis of Landsat MSS and TM images; land area: IBGE (1991a: 169).
[a]Percent deforested refers to deforested land area as a percentage of total land area, as of the year stated.
[b]Average annual deforestation refers to net forest loss per year as a percentage of total land area.
[c]All absolute values are given in square kilometer.

TABLE II. Deforestation in the Andean Amazon, 1980s–1990s.

Country, State	Percent land area deforested[a]		Average annual percent deforested[b]	Land area[c]
	Time 1	Time 2		
Bolivia	1985	1990	1985–1990	
Beni	0.8	1.1	0.05	196 270
Pando	2.5	2.9	0.07	63 830
Santa Cruz	5.4	6.1	0.14	224 690
Other lowland areas[d]	4.4	5.7	0.26	110 870
Overall percent	3.4	4.0	0.13	595 660
Total area deforested[c]	20 220	23 980	752	
Colombia		1996		
Amazonia[e]	ND	5.0	ND	397 260
Orinoquia[f]	ND	13.9	ND	234 050
Overall percent	ND	8.3	ND	631 310
Total area deforested	ND	52 320	ND	
Ecuador		1996		
Morona-Santiago	ND	25.0	ND	24 606
Napo	ND	16.0	ND	37 682
Pastanza	ND	5.0	ND	29 137
Sucumbíos	ND	17.0	ND	22 981
Zamora-Chinchpe	ND	13.0	ND	16 014
Overall percent	ND	15.0	ND	130 420
Total area deforested	ND	19 626	ND	
Perú	1985	1990	1985–1990	
Amazonas	33.0	37.8	0.96	39 249
Loreto	2.1	2.8	0.15	368 852
Madre de Dios	0.5	0.9	0.08	85 183
San Martín	20.8	26.4	1.12	51 253
Ucayali	4.1	5.6	0.30	102 411
Overall percent	5.5	7.0	0.29	646 948
Total area deforested	35 844	45 240	1879	
Venezuela	1982	1995	1982–1995	
Amazonas	0.1	0.4	0.02	178 095
Total area deforested	135	697	43.2	

Sources: Bolivia: deforestation: CUMAT (1992) analysis of Landsat images, in Pacheco (1998: 57); land area: INE (1997a: 5). Colombia: MMA (nd) forest inventory, cited in DANE (1997: 1295); land area: DANE (1997: 14). Ecuador: Land area: INEC (1994: 48). Peru: INRENA (nd) forest inventory, cited in INEI (1997: 283); land area: INEI (1994: 48). Venezuela: MARNR (1997: 9–13) analysis of vegetation maps and Landsat TM images; land area: OCEI (1998: 89).

[a] Percent deforested refers to deforested land area as a percentage of total land area, as of the year stated.

[b] Average annual deforestation refers to net forest loss per year as a percentage of total land area.

[c] All absolute values are given in square kilometer.

[d] Other Bolivian provinces included here are those demarcated as the lowlands in Pacheco (1998: 59) and include Hernando Siles and Luis Calvo (Chiquisaca), Iturralde, F. Tamayo, Sud Yungas and Nor Yungas (La Paz), Chaparé and Carrasco (Cochabamba) and Gran Chaco (Tarija).

[e] The Colombian Orinoco includes the states of Arauca, Casanare, Meta and Vichada.

[f] The Colombian Amazon includes the states of Amazonas, Caquetá, Guainía, Guaviare, Putumayo and Vaupés.

of 595 000 km^2 (Pacheco, 1998: 57). The estimates presented are from analyses of Landsat TM images for the lowlands for 1985 and 1990 (CUMAT, 1992, cited in Pacheco, 1998: 57).During this time, about 700 km^2 were deforested per year, or 0.13% of the region.About 20 000 km^2 (or 3.4% of the region) was deforested as of 1985, rising to 24 000 (or 4.0%) in 1990. Deforestation rates and percentages were highest in Santa Cruz and lower in remote areas of the lowlands.

We define the Colombian Amazon as the 10 states in the Amazon and Orinoco regions of the country, an area covering 631 000 km^2 (DANE, 1997: 14). Available Colombian data do not allow for estimation of deforestation rates over time. That said, data from forestry inventories are available for 1996 at the regional level (MMA, nd, cited in DANE, 1997: 1295). In the Orinoco (Arauca, Casanare, Meta and Vichada), 14% of the forest had been cleared, while in the Amazon (Amazonas, Caquetá, Guainía, Guaviare, Putumayo and Vaupés), 5% was cleared.

The Ecuadorian Oriente includes five states – Morona-Santiago, Napo, Pastanza, Sucumbios and Zamora-Chinchipe – which encompass 130 000 km^2 (INEC, 1994: 48).According to one recent Landsat-based estimate, about 15% of Oriente land was deforested as of 1996 (Rodriguez, 2001). Deforestation is relatively high in Morona-Santiago, Napo and Sucumbíos. The lack of comparable data prevents calculation of deforestation rates in the Oriente, but Rudel and Horowitz (1993: 44) note a very high national deforestation rate of 2.3% per year during 1977–1985.

The Peruvian selva includes both the high and low forests, but these areas cut across state (department) boundaries and only state-level deforestation estimates are available, so we define the selva as the states of Amazonas, Loreto, Madre de Dios, San Martín and Ucayali, an area of 650 000 km^2 (INEI, 1994: 48).[2] Perú has conducted forest inventories of the selva (INRENA, nd, cited in INEI, 1997: 283). Overall, deforestation rose from 36 000 km^2 or 5.5% in 1985 to 45 000 km^2 or 7.0% in 1990, implying an annual average rate of nearly 2000 km^2 or 0.29%. However, state-level estimates indicate large disparities in the extent of deforestation among departments, with Amazonas and San Martín showing 25% deforestation or more by 1990, and average annual rates around 1.0%.

Finally, Venezuela's state Amazonas holds about 180 000 km^2 of the Amazon. An analysis of Landsat images and vegetation maps indicates very little deforestation (MARNR, 1997: 9–13). By 1995, there was less than 1000 km^2 or 0.4% deforested, and during 1982–1995, the annual average deforestation was less than 50 km^2 per year, or 0.02%.

The different data sources in Tables I and III make comparative analysis a risky proposition, but they do suggest contrasting patterns if we focus on interpretations of Landsat imagery.[3] Brazil has a relatively high percentage of land deforested (∼8% in ∼1990) and a relatively high rate (∼0.4% per year). Bolivia has lower percentages deforested (∼4% in 1990) and a modest rate (∼0.1% per year). Venezuela has a very low percentage deforested (∼0.4% by 1995) and very low rate (0.02% per year). Moreover, there is substantial variation among states within and among countries. These contrasts raise questions about how well patterns of demographic change correspond to deforestation estimates.

4. Population change in the Pan Amazon Basin

Table III presents population estimates based on the 1980, 1991 and 2000 censuses for the states of the Brazilian Legal Amazon (see Table III for sources). Overall, the region's population has grown rapidly, from 12 million in 1980 to over 21 million in 2000. Population growth rates declined from the 1980s to the 1990s, primarily in the 'Classical' Amazon states, especially among frontier states such as Rondônia and Pará. But due to the continued demographic expansion underway in the Brazilian Amazon, population densities reached 4 persons per km^2 by 2000. To an extent, the percentage of land area deforested reflects population density; in the late 1990s, both are highest in Maranhão, and also relatively high in Rondônia and Pará. That said, Table III also presents data on urbanization, and shows that in 2000, nearly 70% of the Brazilian Amazon's population resides in towns and cities. It is worth mentioning that again, Maranhão, Rondônia and Pará have relatively low levels of urbanization, and paired with high population densities, these figures suggest that to some degree, rural land settlement does correspond with the extent of land deforested.

Table IV presents indicators of population size, growth, density and urbanization for the Andean Amazon. Figures for each country come from the last two censuses, and italicized numbers are the most recent available estimates based on projections from the last census by that country's state statistical agency (see Table IV for sources). In Bolivia, states entirely within the lowlands had 1.2 million persons in 1976 and 2.1 million in 1992, implying average annual growth at 3.7%, and yielding a population density of 3.3, 60% of it in urban areas. By 2000, the lowland states are projected to encompass 2.8 million persons. Santa Cruz emerges as the most important state, with the largest population and fastest growth, but a

TABLE III. Population change, density and urbanization in states of the Brazilian Amazon, 1980–2000.

State	Population			Average annual percent growth, 1980–1991	Average annual percent growth, 1991–2000	Persons per km^2, 2000	Percent urban, 2000
	1980	1991	2000				
Classical Amazon	5 880 268	9 105 640	11 743 606	4.0	2.8	3.3	69.4
Acre	301 303	417 165	557 526	3.0	3.2	3.6	66.4
Amapá	175 257	288 690	477 032	4.5	5.6	3.4	89.0
Amazonas	1 430 089	2 102 901	2 812 557	3.5	3.2	1.8	74.2
Pará	3 403 391	4 950 060	6 192 307	3.4	2.5	5.0	66.5
Rondônia	491 069	1 130 874	1 379 787	7.6	2.2	5.8	64.1
Roraima	79 159	215 950	324 397	9.1	4.5	1.4	76.1
Other Amazon	6 104 659	7 627 633	9 312 926	2.0	2.2	6.2	66.7
Maranhão	3 996 404	4 929,029	5 651 475	1.9	1.5	17.1	59.5
Mato Grosso	1 369 567	1 778 741	2 504 353	2.4	3.8	2.8	79.4
Tocantins	738 688	919 863	1 157 098	2.0	2.5	4.2	74.3
Legal Amazon	11 984 927	16 733 273	21 056 532	3.0	2.6	4.1	68.1

Sources: 1980 census: IBGE (1991a: 150); 1991 census: IBGE (1991b); 2000 census: IBGE (2001); land area: IBGE (1991a: 169).

TABLE IV. Population change, density and urbanization in Amazonian states of Bolivia, Colombia, Ecuador, Peru, and Venezuela, early 1980s–late 1990s.

Country, State	Population			Average annual percent growth	Persons per km^2	Percent urban
	Early 1980s	Early 1990s	Late 1990s[a]			
Bolivia	1976	1992	*2000*	1976–1992	1992	1992
Beni	168 367	276 174	*366 047*	3.3	1.3	66.2
Pando	34 493	38 072	*57 316*	0.7	0.6	26.3
Santa Cruz	710 724	1 364 389	*1 812 522*	4.3	3.7	72.0
Other lowland areas[b]	310 625	466 627	*577 475*	2.7	4.1	23.7
Total	1 224 209	2 145 262	*2 813 360*	3.7	3.3	59.9
Colombia	1985	1993	*2000*	1985–1993	1993	1993
Amazon	723 486	839 339	1 006 214	1.9	2.1	34.3
Amazonas	54 142	56 399	*70 489*	0.5	0.5	36.4
Caquetá	308 998	367 898	*418 998*	2.2	4.1	43.2
Guainía	17 453	28 478	*37 162*	6.1	0.4	15.5
Guaviare	67 771	97 602	*117 189*	4.6	1.8	23.6
Putumayo	234 305	264 291	*332 434*	1.5	10.6	28.9
Vaupés	40 817	24 671	*29 942*	−6.3	0.5	19.8
Orinoco	883 607	1 077 711	*1 309 579*	2.5	4.2	54.0
Arauca	115 481	185 882	*240 190*	6.0	7.8	50.7
Casanare	212 286	211 329	*285 416*	−0.1	4.7	44.2
Meta	532 000	618 427	*700 506*	1.9	7.2	62.3
Vichada	23 840	62 073	*83 467*	12.0	0.6	15.2
Total	1 607 093	1 917 050	*2 315 793*	2.2	2.9	45.4
Ecuador	1982	1990	*2000*	1982–1990	1990	1990
Morona-Santiago	70 217	84 216	*143 348*	2.3	3.4	28.3
Napo	73 701	103 387	*159 874*	4.2	2.7	22.9
Pastanza	31 779	41 811	*62 110*	3.4	1.4	36.2
Sucumbíos	41 409	76 952	*144 774*	7.7	3.3	26.6
Zamora-Chinchpe	46 691	66 167	*103 233*	4.4	4.1	24.6
Total	263 797	372 533	*613 339*	4.3	2.9	28.3
Perú	1981	1993	*1998*	1981–1993	1993	1993
Amazonas	254 560	336 665	*391 000*	2.3	8.6	35.5
Loreto	482 829	687 282	*840 000*	2.9	1.9	58.0
Madre de Dios	33 007	67 008	*79,000*	5.9	0.8	57.3
San Martín	319 751	552 387	*692 000*	4.6	10.8	60.8
Ucayali	163 208	314 810	*395 000*	5.5	3.1	65.1
Total	1 253 355	1 958 152	*2 397 000*	3.7	3.0	56.0
Venezuela	1981	1990	*2000*	1981–1990	1990	1990
Amazonas	45 667	55 717	*100 325*	2.2	0.3	64.8

Sources: Bolivia: 1976 and 1992 censuses: INE (1997a: 5), Pacheco (1998: 386–387); 2000 population estimates: INE (1997b: 70–72), and for other lowland areas, extrapolation from 1992 assuming a 2.7% annual exponential growth rate (equal to the rest of the lowlands); urban populations: Pacheco (1998: 386–387); land area: INE (1997a: 5), Pacheco (1998: 42). Colombia: 1985 and 1993 censuses: DANE/DNP (2001a); 2000 population estimates: DANE (1999: 25); land area: DANE (1997: 14). Ecuador: 1982 and 1990 censuses: CEPAR (1993: 58); 2000 population estimates: INEC (2001). Perú: 1981 and 1993 censuses: INEI (1994); 1998 population estimate: Webb and Baca (1999: 112); 1993 urban population: INEI (1994: 18); land area: INEI (1994: 48), Webb and Baca (1999: 112). Venezuela: 1981 and 1990 censuses: OCEI (1994: 21); 2000 population estimate: OCEI (2002); land area: OCEI (1998: 89).

[a]Numbers in italics are estimates based on a population projection from the last census by that country's statistical agency.

[b]Other Bolivian provinces included here are those demarcated as the lowlands in Pacheco (1998: 59) and include Hernando Siles and Luis Calvo (Chiquisaca), Iturralde, F. Tamayo, Sud Yungas and Nor Yungas (La Paz), Chaparé and Carrasco (Cochabamba) and Gran Chaco (Tarija).

larger share of its population resided in the state capital. In general, deforestation is greater in Bolivian lowland states where populations are larger and growing faster.

Colombian census data allow presentation of state-level population estimates. While population estimates for the Pan Amazon are to be treated with caution due to likely undercount, those for Colombia are especially delicate due to problems of conducting enumerations in contested zones of insurgency and drug production. That said, the most recent revised population estimates based on census enumerations indicate 1.6 million persons in Colombia's Amazon and Orinoco in 1985, 1.9 million in 1993 and a projected 2.3 million in 2000. Most of the population resides in the Orinoco states. The annual population growth rate overall is 2.3%, somewhat lower than in states of other Pan Amazon countries, but higher in the Orinoco than the Colombian Amazon states. Overall population density is 3.3, similar to other Amazon countries, but higher in the Orinoco than Colombian Amazon states. The higher Orinoco density and growth rate together imply future concentration of population in the east rather than the south. This is especially true in Caquetá and Arauca. Deforestation in Colombia reflects population to some extent, in that population size, growth and density were higher in the Orinoco than the Amazon states, as was the percentage of land area deforested.

The most recent available census enumerations for Ecuador's Oriente indicate populations of 0.3 million in 1982 and 0.4 million in 1990, but projections suggest growth to 0.6 million by 2000. Growth rates are relatively uniform and overall growth is over 4% per year. Population densities are relatively low, below 3.0 in 1990, but urbanization was also limited to under 30%. Densities are high and urbanization low in Morona Santiago, Napo and Sucumbíos, the three states with the highest proportions deforested by 1996. The relatively high population growth rates in the Oriente during the 1980s are also consistent with indications of high deforestation rates there.

In Perú, census enumerations for the selva indicate populations of 1.3 million in 1981 and 2.0 million in 1993, implying an overall growth rate of 3.7% per year, and yielding population densities of 3.0. By 1998, the selva's population is projected to have reached 2.4 million. As with other countries, deforestation to some extent reflects population change. In Amazonas and San Martín, the two states with the highest deforestation percentages, population densities are higher than elsewhere in the selva. Further, while the growth rate is low in Amazonas, most of the population is rural; and while most of San Martín's population is urban, growth is rapid.

Deforestation data lead us to expect to find little population in Venezuela's Amazon. Census enumerations indicate that Amazonas state had a small population in 1981 and 1990, though projections indicate more rapid growth during the 1990s. Nonetheless, for the period for which data are available, population densities remain below other regional estimates and growth is very slow, all of which is consistent with limited deforestation.

Overall, findings for a population–deforestation correspondence are largely but not entirely affirmative. In each country, deforestation is relatively high where populations are generally denser, less urbanized, and in many instances growing faster.

5. Net migration in the Pan Amazon Basin

All that said, it is migration and not population growth *per se* that is often the focus of arguments that population influences deforestation in the Amazon (Wood, 1992; Perz, 2001a). Table V therefore presents estimates of net migration between 1980 and 2000 for the states of the Brazilian Amazon. These estimates, like all that follow, are based on forward projections of population from one census to another (e.g., Shryock and Siegel, 1976: Ch. 23). The projections draw on the age structure of the population at the beginning of the intercensal interval, and employ census-based estimates of fertility and mortality from both censuses, either as reported by national statistical agencies or estimated using standard demographic techniques (Shryock and Siegel, 1976; UN, 1983). Arithmetic interpolations of census-based fertility and mortality estimates allow for us to account for changes in vital rates during intercensal intervals. The projections yield projected populations to the second census date that reflect the effects of age structure and natural increase (i.e., births minus deaths). When compared with the actual populations at the second census date, we can observe differences. Assuming errors of undercount and misreporting are roughly the same in the two censuses, differences must be due to population change due to net migration (i.e., in-migrants minus out-migrants). If the enumerated population exceeds the projection, more people moved into than out of the population, and net migration is positive; if the projection exceeds the enumeration, more people moved out, and net migration is negative. We should expect net migration to be positive in states where deforestation rates are higher.

Given the availability of Brazil's 2000 census, we conducted projections using data from the last three Brazilian censuses. The first projection covers the 1980–1991 period. During the 1980s, deforested land area increased, but net migration shows gains as well as losses. Deforested land area grew particularly fast in Rondônia, Pará, Maranhão, Mato Grosso and Tocantins. Net migration was also highly positive in Rondônia and Mato Grosso, but not the other three states. The second projection covers the 1991–2000 period. We should treat these estimates with more caution, because we base 2000 fertility and mortality rates on slight changes in 1991 estimates, though various fertility and mortality assumptions do not change the results substantially. Deforestation continued during the 1990s, especially in Rondônia, Pará and Mato Grosso. However, all three states had net migration rates near zero. These findings imply a de-linking of migration from deforestation from the 1980s to the 1990s. Given the high rate of urbanization in the Brazilian Amazon, it appears that migration selectively redistributed populations to urban areas, and deforestation was increasingly driven by something other than population change.

TABLE V. Indirect estimates of net migration in the Brazilian Amazon, 1980–2000.

State	Enumerated population in			Projected population in		Net migration[a]		Annual net migration rate[b]	
	1980	1991	2000	1991	2000	1980–1991	1991–2000	1980–1991	1991–2000
Classical Amazon	5 880 268	9 105 640	11 743 606	8 708 318	11 529 113	+397 322	+214 493	+4.8	+2.3
Acre	301 303	417 165	557 526	457 595	549 730	−40 430	+7796	−10.2	+1.8
Amapá	175 257	288 690	477 032	264 403	383 290	+24 287	+93,742	+9.5	+27.2
Amazonas	1 430 089	2 102 901	2 812 557	2 166 036	2 699 108	−63 135	+113 449	−3.2	+5.1
Pará	3 403 391	4 950 060	6 192 307	4 990 529	6 235 535	−40 469	−43 228	−0.9	−0.9
Rondônia	491 069	1 130 874	1 379 787	714 088	1 392 389	+416 786	−12 602	+46.7	−1.1
Roraima	79 159	215 950	324 397	115 667	269 061	+100 283	+55 336	+61.8	+22.8
Other Amazon	6 104 659	7 627 633	9 312 926	8 346 607	9 611 436	−718 974	−298 510	−9.5	−3.9
Maranhão	3 996 404	4 929 029	5 651 475	5 820 964	6 124 560	−891 935	−473 085	−18.2	−9.9
Mato Grosso	1 369 567	1 778 741	2 504 353	1 545 145	2 429 291	+233 596	+75 062	+13.5	+3.9
Tocantins	738 688	919 863	1 157 098	980 498	1 057 585	−60 635	+99 513	−6.6	+10.6
Legal Amazon	11 984 927	16 733 273	21 056 532	17 054 925	21 140 549	−321 652	−84 017	−2.0	−0.5

Sources: 1980 age structure: IBGE (1983); 1991 population and age structure: IBGE (1996); 2000 population: IBGE (2001); total fertility rates and male and female life expectancies at birth: IBGE (1993, 1996).

[a]Net migration is calculated as the enumerated minus the projected population at a given time.

[b]Net migration rates are calculated as net migration divided by the arithmetic mean of the beginning and end of period populations, divided by the period length, multiplied by 1000.

Table VI presents net migration estimates during the last intercensal interval for states situated entirely in the Amazon in the five Andean countries. In Bolivia, the last intercensal interval was 1976–1992. While this interval differs substantially with the deforestation interval in Table II, requiring cautious interpretation, deforestation does correspond with net migration. Net migration was positive in Santa Cruz, where deforestation more rapid; and net migration was negative elsewhere, where deforestation was slower.

In Colombia, net migration estimates require caution due to the census data problems noted earlier. Further, the lack of data on deforestation rates over time prevents an assessment of migration–deforestation correspondence. Given the findings in Table II, we might expect more positive net migration in the Orinoco, where deforestation was greater by 1996. Table VI indicates that net migration throughout the Colombian Amazon was negative, though less so in the Orinoco (especially Arauca and Vichada) than the Amazon. But since we can only compare net migration, a 'flow,' to a 'stock' of deforestation, it remains difficult to tell if deforestation rates in Colombia reflect migration. Given the predominance of negative net migration, there is little reason to expect a correspondence.

In Ecuador, the same problem applies, for deforestation data are only available at one point in time. If we again assume that greater deforestation as of 1996 reflects higher recent deforestation rates, the correspondence with net migration in Table VI appears limited. Among states with proportionally more deforestation, only Sucumbíos shows substantial positive net migration, and Morona Santiago shows negative net migration. To repeat, this comparison of net migration over time ('flows') to deforestation as of a point in time ('stocks') does not really address the migration–deforestation link, if it exists.

In Perú, net migration is positive overall, and substantial gains appear in several states. Given Table II, we would expect large net migration gains in Amazonas and San Martín, where annual deforestation rates are high. Net migration in San Martín was indeed highly positive. However, it was not in Amazonas, and in Madre de Dios, the department with the lowest deforestation rate during 1985–1990, we find the highest positive net migration rate in the Peruvian selva during 1981–1993. Thus, the correspondence between net migration and deforestation in the Peruvian selva appears in some states but not others.

In Venezuela, projections for Amazonas indicate slightly negative net migration. The figure given is based on a relatively high estimate of the total fertility rate. Official estimates hovered around 2.0–2.5 and rose during the 1980s, which stands in stark contrast to the rest of the region which has high but declining fertility rates, so we adopted a more recent and higher fertility estimate, which yields a larger projected population and a negative (as opposed to slightly positive) net migration estimate. In either projection, net migration did not generate substantial population growth, and this is consistent with the low level of deforestation there.

Overall, the findings for net migration and deforestation are mixed in each country with data available. Rondônia and Mato Grosso in Brazil, Santa Cruz in Bolivia, Arauca and Vichada in Colombia, Sucumbíos in Ecuador and San Martín in Perú

TABLE VI. Indirect estimates of net migration during the last intercensal interval, Amazonian states of Bolivia, Colombia, Ecuador, Peru and Venezuela, late 1970s–early 1990s.

Country, State	Enumerated population at time 1	Enumerated population at time 2	Projected population at time 2	Net migration, time 1–time 2	Annual net migration rate[a]
Bolivia	1976	1992	1992	1976–1992	1976–1992
Beni	168 367	276 174	301 376	−25 202	−7.1
Pando	34 493	38 072	61 452	−23 380	−40.3
Santa Cruz	710 724	1 364 389	1 198 420	+165 969	+10.0
Total	913 584	1 678 635	1 561 248	+117 387	+5.7
Colombia	1985	1993	1993	1985–1993	1985–1993
Amazon	723 486	839 339	989 469	−150 130	−24.0
Amazonas	54 142	56 399	74 289	−17 890	−40.5
Caquetá	308 998	367 898	434 478	−66 580	−24.6
Guainía	17 453	28 478	24 997	+3481	+18.9
Guaviare	67 771	97 602	88 499	+9103	+13.8
Putumayo	234 305	264 291	308 471	−44 180	−22.2
Vaupés	40 817	24 671	58 735	−34 064	−130.0
Orinoco	883 607	1 077 711	1 136 344	−58 633	−7.5
Arauca	115 481	185 882	148 171	+37 711	+31.3
Casanare	212 286	211 329	269 082	−57 753	−34.1
Meta	532 000	618 427	684 488	−66 061	−14.4
Vichada	23 840	62 073	34 603	+27 470	+79.9
Total	1 607 093	1 917 050	2 125 813	−208 763	−14.8
Ecuador	1982	1990	1990	1982–1990	1982–1990
Morona Santiago	70 217	84 216	96 621	−12 405	−18.4
Napo	73 701	103 387	100 524	+2863	+3.5
Pastaza	31 779	41 811	41 786	+25	+0.1
Sucumbíos	46 691	66 167	55 963	+10 204	+19.3
Zamora Chinchipe	41 409	76 952	63 619	+13 333	+21.7
Total	263 797	372 533	452 709	−80 176	+5.5
Perú	1981	1993	1993	1981–1993	1981–1993
Amazonas	254 560	336 665	378 084	−41 419	−11.7
Loreto	482 829	687 282	672 325	+14 957	+2.1
Madre de Dios	33 007	67 008	46 330	+20 678	+34.7
San Martín	319 751	552 387	471 090	+81 297	+15.5
Ucayali	163 208	314 810	297 501	+17 309	+6.0
Total	1 253 355	1 958 152	1 865 330	+92 822	+4.8
Venezuela	1981	1990	1990	1981–1990	1981–1990
Amazonas	45 667	55 717	58 379	−2662	−5.8

Sources: Bolivia: 1976 age structures: INE (1976: Table P-3); 1976 and 1992 populations: INE (1997a: 5); total fertility rates: INE (1997a: 20); male and female life expectancies at birth: INE (1997a: 25). Colombia: 1985 age structures: DANE (1986: 87–303); 1985 and 1993 populations: DANE/DNP (2001a); total fertility rates: DANE/DNP (2001b); male and female life expectancies at birth: DANE/DNP (2001c). Ecuador: 1982 age structures: INEC (1992); 1982 and 1990 populations: INEC (1992); total fertility rates: CEPAR (1993: 74); male and female life expectancies at birth: CEPAR (1993: 76). Perú: 1981 age structures: INEI (1983: Table 1); 1981 and 1993 populations: INEI (1994); total fertility rates: INE (1990: 54) and INEI (1996a); male and female life expectancies at birth: INE (1990: 59) and INEI (1996a). Venezuela: 1981 age structure: OCEI (1983: 571); 1981 and 1990 populations: OCEI (1994: 21); total fertility rates: OCEI/PNUD/FNUAP (1996: 87); male and female life expectancies at birth: OCEI/PNUD/FNUAP (1996: 91).

[a]Net migration rates are calculated as net migration divided by the arithmetic mean of the beginning and end of period populations, divided by the period length, multiplied by 1000.

all exhibit positive net migration and high deforestation rates. But there are also many contrary cases with positive net migration and slow deforestation, or negative net migration and rapid deforestation, including Pará, Maranhão and Tocantins in Brazil, Morona Santiago in Ecuador, and Madre de Dios and Amazonas in Perú. In the cases of Colombia and Ecuador, the lack of information on deforestation rates prevents a comparable analysis.

6. Land use as a mediating factor of population and deforestation in the Pan Amazon Basin

One explanation for this limited correspondence concerns intervening factors that mediate the influence of population on environment. The most important such intervening factor for the topic of deforestation is land use. This calls attention to the issue that even if populations are growing and net migration is positive, deforestation most directly results from what households and firms are doing, specifically, whether they are making land use decisions to clear forest (Wood, 1992; Turner et al., 1995; Perz, 2002). Two indicators arguably reflect land use practices in the Pan Amazon to a considerable extent, namely the land area under annual and perennial crops, and the number of cattle (e.g., Serrão and Homma, 1993; Pichón, 1996). If demographic change prompts greater land use for crops and cattle, then deforestation almost inevitably increases. Thus we should expect land use to correspond closely to deforestation.

Table VII presents the percentage of total land area under crops and the heads of cattle per square kilometer for the states of the Legal Amazon, based on enumerations from the last two Brazilian agricultural censuses. In general, the percentage

TABLE VII. Indicators of land cultivation and cattle ranching in the Brazilian Amazon, 1985–1996.

State	Percent land area cultivated[a]		Cattle per square km		Total land area[a]
	1985	1996	1985	1996	
Classical Amazon	0.6	0.5	1.5	3.4	3 574 239
Acre	0.4	0.5	2.2	5.5	153 698
Amapá	0.2	0.1	0.3	0.4	142 359
Amazonas	0.2	0.2	0.3	0.5	1 567 954
Pará	0.9	0.6	2.8	4.9	1 246 833
Rondônia	2.2	1.8	3.2	16.5	238 379
Roraima	0.1	0.6	1.4	1.9	225 017
Other Amazon	2.6	2.7	8.7	15.6	1 508 298
Maranhão	3.2	2.5	9.0	11.8	329 556
Mato Grosso	2.4	3.2	7.3	15.9	901 421
Tocantins	2.4	1.0	13.0	18.8	277 322
Legal Amazon	1.2	1.1	3.6	7.0	5 082 537
Total land/cattle[b]	58 792	57 265	18 485 510	35 538 831	

Sources: 1985 data: IBGE (1990); 1996 data: IBGE (1998).
[a]Cultivated land area and total land area are given in km^2. Cultivated land refers to land under annual and perennial crops and does not include pasture.
[b]Total land area cultivated is given in square kilometer; total cattle is given in heads of cattle.

of land deforested reflects the percentage of land under crops; both are higher in Rondônia and the 'Other' Amazon states.However, the percentage of land under crops declined from 1985 to 1996 nearly everywhere in the Brazilian Amazon, while deforested land area increased. Cattle density accounts for this discrepancy. Not only is deforestation greater where cattle are more prevalent, but cattle density rose especially rapidly where deforestation increased the most, in Rondônia, Pará and the 'Other' Amazon. The importance of 'pecuarização' in the Brazilian Amazon (e.g., Perz, 2001a) and the limited labor required for cattle (e.g., Serrão and Homma, 1993; Pichón, 1996) helps account for the limited correspondence between population growth and net migration with deforestation.

Table VIII presents similar indicators for the states of the Andean Amazon countries. In Bolivia, recent data indicate expanding crop cultivation as well as cattle. While the land use figures presented here refer to a period somewhat later than available deforestation estimates, national figures show similar trends back to 1985. The expansion of land cultivation and cattle is most rapid in Santa Cruz, precisely where deforestation is most rapid.

In Colombia, available sub-national data indicate a decline in cultivated land area, but Colombian data require extra caution given the importance of coca. While data for cattle are unavailable for the Amazon, it is known that Arauca and Caquetá have large herds (Segura and García, 1994), and national estimates indicate growth in the cattle herd (CEGA, 1998: Table 25). The decline in land area under crops in the Colombian Amazon may thus be offset by expansion of the cattle sector, as in Brazil.

In the Ecuadorian Oriente, all states show increases in both the percentage of cropland cultivated and cattle density. If an earlier estimate of a national deforestation rate is to be believed (Rudel and Horowitz, 1993: 44), then the expansion of land use helps account for the rise in deforestation. Interestingly, the proportion of land deforested as of 1996 relatively high in the Oriente when compared to Brazil and Bolivia (compare Tables I and II), though the percentage of land area under crops and the cattle density are lower in the Oriente than the other two countries.

In the Peruvian selva, 1994 agricultural census data indicate cropland percentages that roughly track deforestation, as both are highest in Amazonas and San Martín. Estimates of cattle in 1988 and 1997 show the same correspondence: cattle density is greatest in Amazonas and San Martín.

Finally, in Venezuela, the 1985 agricultural census indicates a low percentage of cropland cultivated and a low cattle density in Amazonas. Though more recent data are necessary to confirm this for the 1990s, these earlier figures are consistent with low deforestation estimates in Amazonas.

Across the Pan Amazon basin, then, deforestation reflects land use profiles and changes. However, this does not exhaust the explanations for the limited correspondence between population and especially net migration and deforestation in the Pan Amazon.

TABLE VIII. Indicators of land cultivation and cattle ranching in the Andean Amazon, 1980s–1990s.

Country, State	Percent land area cultivated[a]		Cattle per square km		Total land area[a]
	1980s	1990s	1980s	1990s	
Bolivia	1988	1999	1990	1999	
Beni	0.1	0.1	11.2	14.1	213 564
Pando	0.2	0.2	0.2	0.3	63 827
Santa Cruz	0.8	3.0	3.1	4.1	370 621
Overall percent/density	0.5	1.8	5.5	7.0	648 012
Total land/cattle[b]	3 272	11 737	3 557 772	4 551 901	
Colombia	1990	1997			
Amazonia[c]	0.3	0.2	ND[e]	ND	403 348
Orinoquia[d]	1.4	1.2	ND	ND	254 335
Overall percent/density	0.7	0.6	ND	ND	657 683
Total land/cattle	4841	4014	ND	ND	
Ecuador	1985	1995	1985	1995	
Morona Santiago	0.2	0.9	4.8	6.9	24 606
Napo	1.3	1.6	2.3	2.2	37 682
Pastaza	0.2	0.4	0.8	0.9	29 137
Sucumbíos	0.1	2.5	2.8	2.6	16 014
Zamora Chinchipe	0.1	1.1	2.8	8.1	22 981
Overall percent/density	0.5	1.2	2.6	3.9	130 420
Total land/cattle	631	1590	337 700	506 000	
Perú		1994	1988	1997	
Amazonas	ND	4.1	4.6	3.4	39 249
Loreto	ND	0.5	0.1	0.1	368 852
Madre de Dios	ND	1.0	0.2	0.4	85 183
San Martín	ND	7.6	1.8	2.2	51 253
Ucayali	ND	1.2	0.6	0.3	102 411
Overall percent/density	ND	2.9	1.2	1.1	646 948
Total land/cattle	ND	18 529	759 000	688 265	
Venezuela	1985		1985		
Amazonas	1.6	ND	0.1	ND	178 095
Total land/cattle	2761	ND	13 984	ND	

Sources: Bolivia: 1988 crop data: INE (1995: 235–239); 1990 and 1999 agriculture data: INE (1999: 369–382); land area: INE (1997: 5). Colombia: cropland data: CEGA (1998: Table 17); land area: DANE (1997a, vol. 1: 14). Ecuador: 1985 data: MINAG (1986: 3, 38); 1995 data: INEC (1996: 7, 225); land area: INEC (2001). Perú: cropland data: INEI (1996b, vol. 1: 30, 39); cattle data: MINAG, cited in Webb and Baca (1999: 745); land area: INEI (1994: 48). Venezuela: agricultural data: OCEI (1988: lxviii, xciv); land area: OCEI (1998: 89).

[a]Cultivated land area and total land area are given in km^2. Cultivated land refers to land under annual and perennial crops and does not include pasture.

[b]Total land area cultivated is given in square kilometer; total cattle is given in heads of cattle.

[c]The Colombian Orinoco includes the states of Arauca, Casanare, Meta and Vichada.

[d]The Colombian Amazon includes the states of Amazonas, Caquetá, Guainía, Guaviare, Putumayo and Vaupés.

[e]No data available.

7. Contextual factors modifying population–deforestation linkages in the Pan Amazon Basin

Another explanation for why population and net migration intermittently correspond with deforestation concerns the contrasting contexts of the countries that share the Pan Amazon basin. It is therefore important to review additional factors that deserve mention if we are to have an adequate basis for interpreting population–environment dynamics in the Pan Amazon.

In Brazil, the Legal Amazon has become an extremely complex and heterogeneous array of spaces where numerous social groups and economic processes are at work. In contrast to the 1970s, when Brazil's military regime had pre-eminent influence over frontier expansion, the crisis of the 1980s led to state retreat, implying the cessation of state-directed colonization and withdrawal of many fiscal incentives (Browder, 1988; Binswanger, 1991). Many interest groups, corporations, NGOs and other local and regional actors have asserted themselves, so now cattle, timber and mineral interests increasingly contest land claims and resource use by indigenous groups, fishers, small farmers, landless peoples, and most famously, rubber tappers (Anderson, 1990; Schmink and Wood, 1992; Hall, 1997). This has resulted in widespread deforestation in some areas where timber and cattle operations predominate (Wood and Skole, 1998; Nepstad et al., 1999), but much less in areas where rubber tappers and other forest-dependent groups predominate (Hall, 1997).

The countervailing social forces behind deforestation that are emerging in the Brazilian Amazon must respond to a changing national and global context. During the 1990s, the state adopted a 'green' discourse when speaking about 'development' in the Amazon, in part as a response to international pressure and threats of frozen bank loans over deforestation in the region. In response, Brazil has created new environmental agencies, a new forestry code that requires 80% of private properties to be kept in forest, and a new National Integrated Policy for the Legal Amazon (Hall, 1997). At the same time, the 'Avança Brasil' program heralds the renewal of top-down infrastructure development projects in the Amazon, something reminiscent of policies from the 1970s that led to deforestation (Carvalho, 1999; Laurance et al., 2001). Avança Brasil, along with the reduction in inflation after the introduction of the Real in 1994, may be prompting new investment in the Amazon in the late 1990s (Fearnside, 2000). These changes may be generating a migration response, for net migration estimates presented here (Table III) are less negative than estimates for 1991–1996 (Perz, 2002), implying renewed population gains due to migration during the late 1990s. This is occurring in an international context of new bank loans for infrastructure and development projects in the Amazon, some driven by European demand for Brazilian soybeans (Hageman, 1996). Whether due to national or international mechanisms, the recent deforestation estimates indicate a rise in annual forest clearing in the Brazilian Amazon from 1998 to 2000 (INPE, 2001).

In Bolivia, much recent attention has focused on the neo-liberal reforms put in place there since 1985. The so-called 'first generation' of reforms in the late 1980s stabilized the national currency and secured preferential terms of trade with other Andean nations. This made key lowland exports such as soybeans and timber more profitable, and both grew in importance manifold by the mid-1990s, in large part due to foreign investment (Pacheco, 1998: Ch. 6). The rise in deforestation due to these policies led to a 'second generation' of reforms focused on regulation of resource management, including new land use and forestry laws in

1996, both designed to encourage more sustainable use practices while generating higher incomes (Pacheco, 1998: Ch. 6). On balance, the effects of these two 'generations' of reforms has been to increase deforestation, primarily by reinforcing a shift to mechanized soybean production in the region and encouraging unsustainable timber extraction, while not providing for adequate enforcement of 'second generation' regulations (Kaimowitz et al., 1999a). Deforestation also appears to occur as much inside indigenous, forest and biological reserves as elsewhere (Kaimowitz et al., 1999b). It remains to be seen whether decentralization of the forestry law to municipal control will result in changes in land management practices (Kaimowitz et al., 1998). As in Brazil, most deforestation appears not to ensue due to the activities of smallholders, who benefited little from the reforms. Smallholders most often focus on labor-intensive and land-efficient coca production rather than land-extensive soybeans, cattle or timber (Pacheco, 1998). As a result, population change plays a limited role in land cover conversion in many areas. On the contrary, smallholders often sell out due to the 'barbecho crisis' of declining productivity on repeatedly cleared plots (Thiele, 1993), allowing soybean and cattle firms to expand and prompting rural–urban migration by poor families (Kaimowitz et al., 1999a).

One can scarcely discuss the Colombian Amazon without reference to that country's insurgency, coca production, or oil exploration. As in Brazil and elsewhere, recent waves of settlement in the Colombian Amazon reflect high concentrations of land ownership and periodic violence in other parts of the country (Munévar, 1991; González Arias, 1998; Cubides and Domínguez, 1999). Peasant resistance to rural violence partly underlies contemporary insurgency movements such as the FARC, who have in some sense served as protectors of peasant communities and brokers of coca production in many parts of southern and eastern Colombia (e.g., Vargas Meza, 1998). In the mid-1980s, paramilitary crackdowns, high cocaine prices and the breakdown of then-president Betancur's call for a cease-fire bolstered support for the FARC and prompted new land settlement and increased coca production in the Colombian Orinoco and Amazon (Salgado Ruiz, 1995; González Arias, 1998: Ch. 2; Vargas Meza, 1998). By 1993, coca accounted for more land area cultivated than all legal crops combined in Putumayo (Salgado Ruiz, 1995: 161). A second surge in support for insurgents and coca occurred during the late 1990s as a result of the Samper crisis, which occurred in the context of an agricultural economic crisis, which again bolstered support for the FARC and coca cultivation (Vargas Meza, 1998; Dugas, 2001). Aside from support of coca production, establishment of new oil exploration sites in the Orinoco and Amazon have drawn the attention of insurgents and fostered land clearing. Implementation of oil infrastructure is closely tied to migration patterns in Casanare and other parts of the Orinoco and Amazon (Domínguez, 1999; Flórez, 1999). The Pastrana administration has cultivated more favorable ties with US oil interests and Washington politicians, a key factor leading to securing $1.6 billion in aid for Plan Colombia, a military operation to protect oil infrastructure and eradicate coca plantations (Petras, 2001). This uncertain political economic context has major ramifications for land use practices by traditional and indigenous communities in the Colombian Orinoco and Amazon, and at the same time makes assessment of land cover change very difficult.

In Ecuador, an interpretation of population–deforestation linkages can be informed by discussion of oil exploration-led frontier expansion, various social responses and spillovers from Plan Colombia. Land settlement in Ecuador's Oriente has proceeded slowly and over a long period of time, but accelerated in the 1970s following oil discoveries during the 1960s (Rudel and Horowitz, 1993). Oil roads and drilling sites do account for some deforestation, but their effects on land cover are largely indirect, coming via the unintended draw to poor populations in the Andes (Kimerling, 2000). As elsewhere in the Amazon, land use systems among smallholders have evolved over time, from annuals to cash crops including coca and coffee, and now increasingly toward cattle (Pichón, 1997; Eberhart, 1998; Marquette, 1998). Aside from the migration response, which has stimulated deforestation, has been the responses by indigenous groups in the Oriente to environmental degradation in tribal territories (Uquillas, 1989). While many groups have resisted oil exploration and its negative impacts in many ways (Kimerling, 2000), some have taken advantage of the new roads to exploit forest resources, including by ranching (Uquillas, 1989). In contrast to the Amazon in Bolivia and parts of Brazil, land use in the Ecuadorian Oriente is not generally geared for exports, in part due to political and economic instability (EIU, 2000a). This has recently begun to change as Plan Colombia drives drug production into northeastern Ecuador (Bannowsky, 2001).

In Perú, changes in the regional and national context may be modifying the place of the selva in the larger society. Like other Andean countries, Perú's selva has experienced slow colonization by Andean families seeking additional land (Carpio, 1988; Mora, 1991; Santos-Granero and Barclay, 1998). This 'Andeanization' of the selva often reflects seasonal migration strategies paired with Amazon land use to supplement Andean incomes (Collins, 1988), but may also lead to permanent settlements and expanding deforestation over time (Dourojeanni, 1990; Imbernon, 1999; Schjellerup, 2000). During the 1980s and 1990s, the insurgent group Sendero Luminoso encouraged smallholder coca production to finance land settlement and support a leftist guerilla campaign against the Peruvian state, and these activities fostered deforestation in remote parts of the selva (Bedoya and Klein, 1996). The capture of insurgency leaders greatly reduced the influence of the Sendero Luminoso, but high if volatile coca prices have persisted, along with illicit deforestation. At the same time, cattle ranching has emerged as an important activity in the selva, largely a response to national economic growth during the 1990s and plans for a transoceanic highway through Brazil and Perú (Loker, 1993; Varese, 1999). This occurred in the context of the Fujimori presidency when Perú embarked on a strict neoliberal economic program that encouraged oil exploration in the selva and growth in key exports (EIU, 2000b).

The Amazon in Venezuela remains remote from most development planning and population change. Available literature emphasizes the need for regional development in order to improve human welfare (Santana Nazoa, 1991; Carrillo and Perera, 1995; FKA, 1995). This is not surprising given Venezuela's poor recent economic performance (EIU, 2000c).

8. Conclusion

Population and net migration comprise a key part of the demographic dimension of deforestation in the Pan Amazon basin. However, their correspondence with deforestation is limited due to intervening variables such as land use, as well as contextual factors such as frontier development policies, which also influence land cover change. Deforestation in the Amazon reflects many processes, beginning with household land use, which reflects local population change, which reflects regional economic change, which reflects national development policies, which responds to national and external political and economic circumstances (Perz, 2001a; Wood, 2002).

These conclusions raise questions about less-studied aspects of land cover change in the Pan Amazon. For one thing, we need to attend more closely to micro-level processes that more directly influence land use and land cover change. After all, deforestation reflects first and foremost the decision of a social actor to cut trees down. Demographers studying environmental issues such as deforestation are only beginning to analyze household-level decision processes (Perz, 2001b). However, there is good theoretical reason to expect that demographic processes at the household level influence land use decisions in the Amazon (Walker and Homma, 1996), and available empirical evidence suggests that household age structure does affect land use decisions (Pichón, 1997; Marquette, 1998; Perz, 2001b). Similarly, the composition of migrant flows, not only with respect to rural/urban destination but also to sex and age composition, likely influences land use decisions in new frontier areas (Marquette, 1998).

There is also a need to go beyond deforestation and consider other aspects of land cover change. Deforestation analyses tend to overlook forest fragmentation, focusing on the total land area cleared rather than the geometry and spatial distribution of clearings, which also has important implications for ecosystems (Skole and Tucker, 1993; Schelhas and Greenberg, 1996). Deforestation analyses have also neglected the question of forest impoverishment by timber extraction, and consequent threats of uncontrolled fires in the Amazon (Nepstad et al., 1999). One area getting more attention is secondary growth, that is, the natural vegetation that appears if cleared plots are then left alone. Secondary vegetation now covers substantial portions of deforested land in the Amazon (e.g., Alves and Skole, 1996; Moran et al., 1994). However, the social processes leading to the emergence of secondary growth are little understood for non-indigenous populations in the Amazon (Scatena et al., 1996; Fujisaka and White, 1998; Walker, 1999; Coomes et al., 2000). Finally, there is very little research on the overall farm systems that tend to be adopted by households with certain capital and labor endowments (Walker et al., 2002).

Aside from additional research, the foregoing discussion calls for attention to recent policy proposals to better manage forest resources and sustain human populations in the Pan Amazon. One recurrent theme in policy prescriptions is the need for a stronger state presence. In parts of the Brazilian and Bolivian Amazon, state governments have adopted 'agro-ecological zoning' of land use (Kaimowitz et al., 1999a; Mahar, 2000), where agencies identify areas appropriate for agriculture, forestry or forest preservation based on rainfall, biodiversity, soil quality and market proximity in order to focus resource use in appropriate locations (Schneider et al., 2000). Related to zoning plans are recent calls to predicate new roads and state credit on similar biophysical and market factors (e.g., Schneider et al., 2000; Laurance et al., 2001). Also related to zoning are concerns about indigenous land demarcation and secure private property rights, both of which have been argued as means of resolving land conflicts and reducing 'resource mining' following deforestation (e.g., Van Cott, 1994; Schneider, 1995; Schwartzman et al., 1996; Alston et al., 1999).

Another recurrent theme in many policy suggestions concerns increased popular participation in policy formulation and/or greater attention to communities and smallholders. Bolivia's 1996 land use and forestry plans have been delegated to local administrations (Kaimowitz et al., 1998), where analysts have called for greater allocation of volume- and not land-based timber concessions, as well as incentive packages targeted to smallholders who use less land and produce more per hectare (Kaimowitz et al., 1999a). Related to suggestions for more attention to smallholders are calls to support small farm agroforestry systems, which allows for diversification of income sources while maintaining greater forest cover than traditional agriculture (e.g., Vosti et al., 1998; Browder and Pedlowski, 2000). In recent years, 'the community' has emerged as a key to rural development and resource conservation (Agarwal and Gibson, 1999). Communities and local organizations may serve as two-way conduits to educate local peoples e.g., about the controlled use of fire, while also informing state agents about likely environmental impacts of e.g., new infrastructure projects or credit policies (e.g., Hall, 1997; Carvalho, 1999).

A third theme in policy discussions concerns international agreements that predicate certain financial transactions on sustainable resource management. This reflects interest in placing economic values on intact ecosystem services in order to provide an incentive to preserve ecosystems (Costanza et al., 1997). There has been considerable attention devoted to developing global markets for trading of carbon emission rights, as via the Kyoto Protocol (Grubb et al., 1999), whereby a country emitting carbon due to tropical deforestation could 'trade' additional deforestation, and thus carbon emissions, in return for money from another country seeking to pay for its own emissions increases.

Many of these policy prescriptions derive in one fashion or another from concerns about demographic responses to previous state actions that led to subsequent deforestation in the Pan Amazon. Zoning in the Brazilian Amazon partly reflects concerns about new infrastructure projects there, which may, as in the past, be encouraging migration, land settlement and deforestation. Similarly, attention to incentives for smallholders reflects concerns about previous top-down policies that tended to favor large-scale firms, often yielding large-scale deforestation. New policy prescriptions, based on lessons from previous experiences, offer possible paths for Pan Amazon countries to help support the livelihoods of Amazon populations while conserving the forest environment. What is needed now is political leadership from outside as well as within the Pan Amazon community, both of which are likely to be necessary for substantial constituencies of Amazon landholders to adopt more sustainable land use practices (Uhl and Nepstad, 2000).

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Notes

[1] We recognize that there are many ways to demarcate the Pan Amazon basin, such as by hydrology, geology, vegetation or language groups. In our case, data limitations prevent consideration of the Guianas and Suriname. While our choice of countries and provinces is somewhat artificial, we do include in our analysis the vast majority of the land and people in the basin as it is defined by most criteria (e.g., Santana Nazoa, 1991: Ch. 1).

[2] The states of Amazonas and San Martín fall largely within the high forest or selva alta, and the other states we include fall largely in the low forest, or selva baja. The selva alta occurs at higher altitudes and generally has older and denser settlements (e.g., Collins, 1988).

[3] We also recognize that even with satellite-based estimates, comparisons for montane and lowland forest cover are difficult. Shadows due to topographic relief in the highland forests may hide deforestation, while this is less of a problem in lowland forests.

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