
Population Growth, Human Development, and Deforestation in Biodiversity Hotspots

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Abstract: *Human population and development activities affect the rate of deforestation in biodiversity hotspots. We quantified the effect of human population growth and development on rates of deforestation and analyzed the relationship between these causal factors in the 1980s and 1990s. We compared the averages of population growth, human development index (HDI, which measures income, health, and education), and deforestation rate and computed correlations among these variables for countries that contain biodiversity hotspots. When population growth was high and HDI was low there was a high rate of deforestation, but when HDI was high, rate of deforestation was low, despite high population growth. The correlation among variables was significant for the 1990s but not for the 1980s. The relationship between population growth and HDI had a regional pattern that reflected the historical process of development. Based on the changes in HDI and deforestation rate over time, we identified two drivers of deforestation: policy choice and human-development constraints. Policy choices that disregard conservation may cause the loss of forests even in countries that are relatively developed. Lack of development in other countries, on the other hand, may increase the pressure on forests to meet the basic needs of the human population. Deforestation resulting from policy choices may be easier to fix than deforestation arising from human development constraints. To prevent deforestation in the countries that have such constraints, transfer of material and intellectual resources from developed countries may be needed. Popular interest in sustainable development in developed countries can facilitate the transfer of these resources.*

Keywords: deforestation rate, global development data, human development index, regional development patterns, sustainable development

Crecimiento Poblacional, Desarrollo Humano y Deforestación en Sitios de Importancia para la Biodiversidad

Resumen: *La población humana y sus actividades de desarrollo afectan a la tasa de deforestación en sitios de importancia para la biodiversidad. Cuantificamos el efecto del crecimiento y desarrollo de la población humana sobre las tasas de deforestación y analizamos la relación entre estos factores causales en las décadas de 1980 y 1990. Comparamos los promedios del crecimiento poblacional, el índice de desarrollo humano (IDH, que mide el ingreso, la salud y la educación) y la tasa de deforestación y calculamos las correlaciones entre estas variables para países que contienen sitios de importancia para la biodiversidad. Cuando el crecimiento poblacional era alto y el IDH bajo, la tasa de deforestación era alta, pero cuando el IDH era alto, la tasa de deforestación era baja, a pesar de un crecimiento poblacional alto. La correlación entre variables fue significativa para la década de 1990 pero no para la de 1980. La relación entre crecimiento poblacional e IDH tuvo un patrón regional que reflejó el proceso histórico del desarrollo. Con base en los cambios temporales en el IDH y en la tasa de deforestación, identificamos dos causas de deforestación: selección de políticas y restricciones de desarrollo humano. La selección de políticas que descuidan la conservación puede causar la pérdida de bosques aun en países que están relativamente desarrollados. Por otra parte, la falta de desarrollo en otros países puede incrementar la presión sobre los bosques por satisfacer las necesidades básicas de la*

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población humana. La deforestación resultante de la selección de políticas puede ser más fácil de reparar que la resultante de restricciones de desarrollo humano. Para prevenir la deforestación en los países que tienen tales restricciones, es posible que se requiera la transferencia de recursos materiales e intelectuales desde países desarrollados. El interés popular en el desarrollo sustentable en países desarrollados puede facilitar la transferencia de estos recursos.

Palabras Clave: Datos de desarrollo global, desarrollo sustentable, índice de desarrollo humano, patrones de desarrollo regional, tasa de deforestación

Introduction

The theoretical appeal and policy significance of the effects of population growth and human development on deforestation in developing countries has led to a substantial increase in information on these topics over the past years. For example, Kaimowitz and Angelsen (1998) review 32 quantitative studies in the tropics. Biodiversity hotspots also have been highly studied. These regions of the world support numerous plant and animal species, and these species are facing extinction because of high population growth and development activities (Cincotta et al. 2000; Myers et al. 2000). Geist and Lambin (2002) provide a meta-analysis of 152 subnational studies on deforestation. These and other deforestation studies have a wide spatial perspective.

The temporal context of deforestation, however, has received less attention. There have been no studies on temporal variation in deforestation and its population or development correlates. Such studies are needed to understand why deforestation rate increases in some countries but decreases in others and what role population growth and human development play in such variation. Furthermore, temporal analysis may suggest whether population and development variables of the countries that have high rates of deforestation at different times are similar. If not, then factors other than population and human development may affect deforestation rates in these countries. Furthermore, over time, trends in deforestation across countries can reveal challenges for conservation. For example, deforestation rate in Argentina and Costa Rica in the 1990s was 0.8%/year. In Argentina, however, the rate increased from 0.57%/year in the 1980s, whereas it decreased in Costa Rica from 2.6%/year over that period (WRI 1997; World Bank 2001). In addition, deforestation trends may indicate whether development is sustainable in different countries, and information on trends advances knowledge and policy on sustainability (Sachs 2002).

We studied temporal variation in population growth, human development index (HDI, which is a measure of income, health, and education), and deforestation rate in biodiversity hotspots in developing countries (broadly, countries in Asia, Africa, and Latin America) in the 1980s and the 1990s. We investigated whether the HDI values were similar or different among countries that had

the highest rates of deforestation in these two decades. Our work should contribute to sustainability science and to the five target areas—water, energy, health, agriculture, and biodiversity, the so-called WEHAB—for sustainable development identified at the Johannesburg Summit (United Nations 2002; Clark & Dickson 2003).

Methods

Hotspots

Hotspot regions are undergoing rapid loss of habitat (Myers et al. 2000). Each hotspot is a biogeographic unit and features a separate biota or a community of species. The number of hotspots has increased over time. In 1988 there were only 10 hotspots, all in the tropics. In 1990, 8 other areas, 4 each in the tropics and in Mediterranean-type zones, were identified (Myers 1988, 1990). The current tally of 34 hotspots includes biogeographic regions on islands (Conservation International 2005). The boundaries of hotspots are not usually coterminous with the political boundaries of countries, and some hotspots occur only in one part of a country, such as Southwest Australia and South-Central China. Others, such as Caribbean, Mesoamerica, California Floristic Province, Indo-Burma, Sundaland, Caucasus, and Eastern Arc, include areas in two or more countries. Hotspots such as New Zealand and Madagascar encompass the entire country.

Hotspots cover only 2.3% of the Earth's land surface, but they include 50% of the world's vascular plants species and 42% of the world's species in four vertebrate groups. Sixteen hotspots are in the tropics, where the pressure of human population growth and development on biodiversity is high, which means it is important to examine these issues in hotspot areas.

Human Development Index

The HDI index was developed by the United Nations Development Program (UNDP) in 1990 to measure improvements in income, life expectancy, and education resulting from economic growth (UNDP 1990). The index data are now available for most countries at 5-year intervals from 1975 onward.

The HDI for a country is calculated in two steps: first, data on particular human development statistics are calculated, and, second, the averages of these statistics are calculated. The human development statistics are gross domestic product (GDP) per capita; life expectancy; and adult literacy rate and enrollment in educational institutions. Each of the three components is assigned equal weight in the calculation of the index. Values for these components for a country are compared with the worldwide goals for human development statistics set by UNDP. These goals are revised upward over time. The current goals are income of US\$40,000/year, life expectancy of 85 years, and 100% adult literacy and combined primary, secondary, and tertiary gross enrollment ratio (UNDP 2001). Based on comparison with the goal values, HDI values for countries vary from 0.258 to 0.939. Forty-eight countries have high HDI, between 0.8 and 0.99; 77 have medium HDI, between 0.5 and 0.79; and 35 have low HDI, between 0.258 and 0.49 (UNDP 2001). Developed countries—and some developing countries such as Chile, Argentina, Slovenia, Czech Republic, Qatar, Korea, and Singapore—have high HDI. Countries with a medium HDI include most Asian and Latin American countries, and those with a low HDI include mostly African countries. Although HDI values have increased over time for most countries, there are some exceptions (UNDP 2003).

We examined 30 countries in Asia, Africa, and Latin America and considered each as unit of analysis for three conceptual and practical reasons. First, policies that affect population growth, human development, and deforestation usually have countrywide application. Second, projects that involve deforestation, at least in theory, promise to benefit the country as a whole. Third, the data are more reliable at the country level, especially for developing countries.

Data on population growth, HDI, and deforestation rate for the 30 countries (7 in Africa, 9 in Asia, and 14 in Latin America) were compiled from World Bank (1992, 2002), UNDP (2001), and WRI (1997), and World Bank (2001) sources, respectively. The use of rate of deforestation as an indicator of the state of the forests in a country is not without a caveat. The rate may be low currently because good policies on population and human development may be in place, but it may also be low currently if all accessible forests were logged in the past.

We used *t* tests to compare groups of countries and computed correlation coefficients for the variables. We tested the significance of income inequality within countries for population growth by calculating correlation coefficient for population growth and the Gini coefficient (measure of income inequality within countries) (World Bank 2000). Correlation between population growth and human development in the 20 countries that led in HDI and in the G-7 countries (United States, Canada, United Kingdom, France, Germany, Italy, and Japan) that led in wealth was analyzed to understand the historical trend in development process. We drew scatter plots to exam-

ine the variation between the HDI and rate of deforestation over the two decades. We determined whether the variation between HDI and deforestation rate was similar to the environmental Kuznets curve. This curve predicts that deforestation rate in developing countries will follow an inverted-U curve; that is, deforestation will first increase, then reach a plateau, and finally decrease as income increases in these countries (Cropper & Griffith 1994; World Bank 2000).

Results

Deforestation rates in the countries varied from -1.2% to 3.1% /year, population growth from 0.9% to 3.8% /year, and HDI from 0.34 to 0.80. Rate of deforestation was positively correlated with population growth and negatively correlated with HDI in the 1990s. In all the countries, population growth decreased and HDI increased over the two decades. These trends were consistent with the worldwide decline in fertility, increase in life expectancy, and gains in universal education over the past three decades. In contrast, change in deforestation rate was not significant over that period. The rate dropped from 1.30% /year in the 1980s to 0.96% /year in the 1990s ($p = 0.17$) (Table 1). At the group level, deforestation rate increased in 11 countries ("group of 11"): Chile, Nicaragua, Guatemala, Madagascar, Nigeria, Cameroon, Benin, Côte d'Ivoire, Ghana, Indonesia, and Sri Lanka. For this group, in the 1990s, population growth was 2.43% /year, HDI was 0.55, and deforestation rate was 1.73% /year. In contrast, deforestation rate decreased in 19 countries ("group of 19"): South Africa, India, China, Thailand, Laos, Vietnam, Malaysia, the Philippines, Venezuela, Columbia, Ecuador, Bolivia, Mexico, Honduras, Costa Rica, Panama, Dominican Republic, Brazil, and Paraguay. For this group of countries, population growth was 1.92% /year, HDI was 0.69, and deforestation rate was 0.51% /year.

Table 1. The mean population growth, human development index (HDI), and deforestation rate in the 1980s (top number) and 1990s (bottom number) in countries in hotspot areas and in two subsample country groups.

Country sample	Population (%/year)	HDI	Deforestation (%/year)	p
30 countries ^a	2.52	0.60	1.30 ^c	0.17
	2.11	0.64	0.96 ^c	
Group of 19 ^b	2.40	0.70	1.43	
	1.92	0.74	0.51 ^c	
Group of 11 ^b	2.80	0.52	1.02	0.001
	2.43	0.56	1.73 ^c	

^aThirty countries within the world's 25 hotspots.

^bIn 19 countries the rate of deforestation decreased in the 1990s compared with the 1980s, whereas in 11 countries the rate increased over that period.

^cBased on *t* test.

Table 2. Correlation coefficient among population growth, human development index (HDI), and deforestation rate for the countries sampled (30) and two country-group subsamples (19 and 11) in the 1980s (top number) and 1990s (bottom number).*

Country sample	Population growth—HDI (r)	p	Population growth—deforestation rate (r)	p	HDI—deforestation rate (r)	p
30	-0.52	0.00	0.29	0.12	1.30	0.12
	-0.68	0.00	0.53	0.00	-0.40	0.02
19	0.05	0.80	0.53	0.02	1.43	0.13
	-0.33	0.13	0.34	0.17	0.51	0.17
11	-0.75	0.00	0.29	0.38	1.02	0.70
	-0.86	0.00	0.56	0.07	1.73	0.08

*See footnote in Table 1 for explanation of country samples.

The group of 11 countries and the group of 19 countries represented regional trends in population growth, HDI, and deforestation rate. The group of 11 had six countries from Africa, where population growth was 2.8%/year, HDI was 0.46, and deforestation rate was 1.9%/year. The group of 19 countries included 11 countries from Latin America, where population growth was 2.0%/year, HDI was 0.72, and deforestation rate was 0.7%/year.

The correlation between population growth and deforestation rate was positive and significant ($r = 0.53, p = 0.00$), whereas the correlation between HDI and deforestation rate was negative and significant ($r = -0.40, p = 0.02$) for the sample in the 1990s (Table 2). In that decade, the correlation between population growth and HDI was negative and significant for the sample ($r = -0.68, p = 0.00$) and for the group of 11 ($r = -0.86, p = 0.00$). For the group of 19 countries, however, the correlation was not significant ($r = -0.33, p = 0.13$). The correlation between population growth and the Gini coefficient was weak ($r = 0.08$). The correlation coefficient for population growth and HDI for the 20 countries in the world, which led in HDI was not significant ($r = 0.35, p = 0.13$), but it was positive for the seven wealthiest countries ($r = 0.77, p = 0.04$). The scatter plot for HDI versus deforestation rate for the 1980s or the 1990s showed that highest rates of deforestation in these decades were in the countries that were dissimilar in HDI values (Fig. 1). In the 1980s, the most deforestation occurred in Costa Rica, the Philippines, and Thailand; these countries were the leaders among hotspot countries in HDI values. In contrast, in the 1990s the most deforestation occurred in Côte d'Ivoire, Benin, and Nigeria; these countries were lagging in HDI values. The scatter plot did not support the environmental Kuznets curve for the 1980s or the 1990s.

Discussion

The correlation between deforestation rate and population growth or HDI was significant for one time period but not for the other. This suggests that the relation-

ship among these variables is not absolute over time and therefore cannot be understood in a static time frame. Our results underscore that the deforestation situation in hotspots should be a matter of concern. Not only was the drop in deforestation statistically not significant over the decade, but its rate was also high (0.96%/year) in the 1990s. This rate is higher than the rate of tropical deforestation (0.6%/year), which is considered a threat to biodiversity and the environment (WRI 2000). These results may also indicate, in part, a failure of global conservation efforts because, until and into the 1990s, influential bodies (e.g., the Brundtland Commission) and high-profile conferences (e.g., the Earth Summit), had warned against deforestation in developing countries. Still, deforestation increased in more than one in three countries in hotspots. This rise indicates the need to learn more about the causes and processes that affect deforestation rates in hotspot countries.

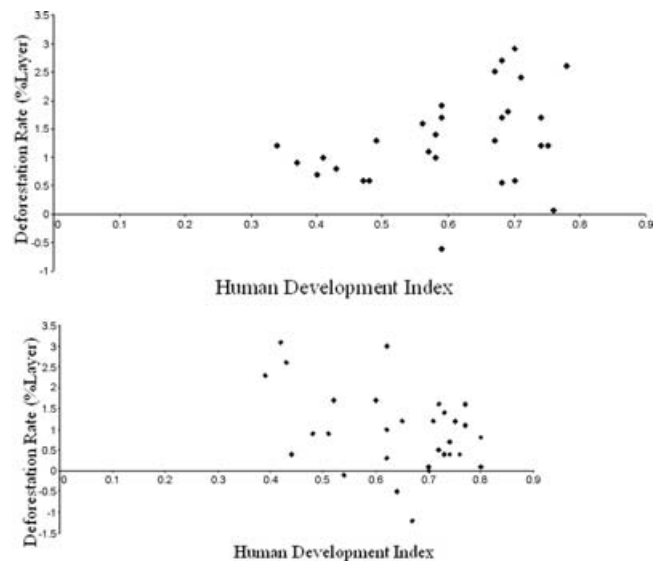


Figure 1. Human development index and deforestation rate in the 1980s (top) and 1990s (bottom) in 30 countries that contain hotspots.

Population Growth, HDI, and Deforestation Rate

Population growth, HDI, and deforestation rates and their regional pattern in the two groups of countries suggest that the effect of population growth on deforestation rate may be uneven across countries and HDI may mitigate that effect. In the early stage of development, for example in the group of 11 countries, population growth was high, HDI was low, and deforestation rate was high. Later, associated with a rise in human development, deforestation rate decreased, despite high population growth. This pattern also occurred in the group of 19 countries. Thus, population growth may be an important factor for deforestation in the countries that lag in human development but may be less of a threat as human-development gains are made. This result provides partial support for the suggestion that the importance of population growth in deforestation studies has been overemphasized (Geist & Lambin 2002).

The group of 19 countries included 11 countries from Latin America, where high population growth and impressive gains in human development coexist. Population growth in Latin America has been examined in the development literature from the perspective of income inequality. The region has the highest income inequality in the world, which may be the result of nonparticipatory development, for example, in Brazil (Drèze & Sen 1998; Hausmann & Székely 2001). This inequality, in turn, leads to disproportionate household sizes across the population. For example, families in the top 10% of the income distribution have, on an average, 1.4 children, whereas those from the poorest 30% have 3.3 children (Hausmann & Székely 2001). Although correlation between population growth and the Gini coefficient was not significant for the 11 Latin American countries that comprised the group of 19, we suggest that the effect of income distribution on population growth, human development, and deforestation rate merits detailed study.

The correlation between population growth and HDI in the hotspots and other countries may reflect the historical process of development. At the lower end of development, the correlation coefficient may be negative, marked by high population growth and low HDI, as was the case for the group of 11 countries. In the middle range of development, correlation may change from negative to null because in some countries human development may drive down population growth, whereas in others it may not. The downward pressure of human development on population growth is called the "feedback effect" (Bloom & Canning 2001). In the group of 19 countries the effect was noticeable in Thailand and Brazil, where population growth dropped by 30–50% over the 1990s compared with the 1980s, but not in the Philippines and Malaysia, where the population decrease was only 5–10%. Again, the correlation between population growth and human development was null for the 20 countries that led in hu-

man development. In the most developed countries (G-7 group) however, the correlation was positive and that may be because in these countries there are more opportunities for education and skills development and thus more skilled workers.

The dissimilar relationship between population growth and HDI in the two groups of countries in hotspots may be a contribution to the old debate in the population and development literature. In the 1950s and 1960s, results of short-term studies revealed the negative impact of rapid population growth on human development, but in the 1980s results of long-term studies showed that the effect of population growth was neutral (Kelley 2001). The current perception, based on studies spanning a few decades, is that the effect is intermediate between these extremes. Kelley (2001) suggests that these varied perceptions result from differences in the length of time over which studies were conducted. However, we found both negative and null correlation in a single time frame. The result has at least methodological implications because it suggests that developing countries are heterogeneous in population growth and human development, and therefore need to be studied in groups based on the values for population and development parameters.

The population growth–HDI model cannot explain the trend or rate of deforestation in some countries (i.e., China, India, Vietnam, Chile, Indonesia, and Sri Lanka). In the first three countries deforestation decreased and its rate was negative, population growth varied from 1.1 to 1.8%/year, and HDI varied from 0.59 to 0.69. In contrast, deforestation in Chile, Indonesia, and Sri Lanka increased and its rate was positive. In Indonesia and Sri Lanka, the rate of deforestation was high (1.2 to 1.6%/year). The difference in the deforestation situation in these groups of countries may be related to whether the country has an open or closed economy. In a closed economy, such as India's, the demand for forest products is met from forests within the country and that provides thrust to afforestation programs. There is no impetus to increase the area under forest in open economies because the products can be imported (Foster & Rosenzweig 2003).

Additionally, an open or closed economy may also determine how human skills are used in the manufacturing sector in these countries. In closed economies human skills are leveraged to develop substitutes for the forest products so that forests can be saved. In contrast, in open economies harvested forests and human skills add value to the products. For example, India has almost completely substituted wood with cement and steel for the production of railway sleepers (Lal 2004). In contrast, Chile and Indonesia increased the production of wood-based panel and paper products by 500% during 1986–1988 to 1996–1998 (WRI 2000). Thus, economic policies can affect deforestation in a country. Other policies, such as those relating to agriculture, animal husbandry, and energy use, can also affect forests (Fig. 1).

HDI and Deforestation Rate

High rates of deforestation in the 1980s were in the countries that had among the highest HDI values, and in the 1990s these rates were in the countries that had among the lowest. The causes of deforestation in these countries may be different and characterized as policy choices and human development constraints in respective years. Policy choices may become a cause of deforestation when countries that are ahead in human development adopt policies that disregard conservation. The rate of deforestation in Costa Rica, the Philippines, and Thailand was high in the 1980s because policies in these countries favored overlogging, clearing for agriculture, and conversion in ranch land (Bawa & Dayanandan 1997; Kaimowitz & Angelsen 1998). In contrast, high rates of deforestation in Côte d'Ivoire, Benin, and Nigeria, in the 1990s resulted from human development constraints marked by underproductive agriculture and high dependency on firewood (WRI 2000; CIA 2003; LSU 2004).

The variation between HDI and deforestation rate in hotspot countries provides two lessons. First, human development may not prevent unsustainable policies. It may, however, facilitate a decrease in deforestation once these policies are reversed. For example, deforestation rate substantially dropped in Costa Rica, the Philippines, and Thailand in the 1990s when the policies of the 1980s were reversed. Second, lack of human development may inevitably cause an increase in deforestation rate, as the example of Côte d'Ivoire, Benin, and Nigeria shows. The rise in deforestation rate in these countries also explains why international appeals to prevent deforestation did not work in some countries.

Measures of Sustainable Use of Forests

Our results show that low human development may cause high rates of deforestation in hotspots. Furthermore, although gains in human development may significantly reduce deforestation, countries can experience dramatic differences in deforestation rate despite the gain. These results indicate that different tactics may be needed to maintain sustainable use of forests across countries. In countries that are ahead in human development, dissemination of information on the value of biodiversity or the benefits of conservation may reverse unsustainable policies. Such efforts may not be enough for the countries that lack human development. These countries may need assistance with resources—material and intellectual—to improve agriculture and energy use so that pressures on the forests can decrease. The food situation in these countries has received attention of international organizations, but the energy use in these countries may require higher priority than it has received so far. In countries in hotspot regions, 75% of round wood produced is used as fuel, and in countries such as Benin this proportion is 95% (WRI 2000). To put this into perspective, the proportion of

round wood produced for fuel in developed countries is only 10%. Thus, for countries in hotspot regions material resources and scientific technology may be needed to reduce the pressure on the forests to supply basic needs.

The transfer of material and intellectual resources to countries in hotspot regions will be from developed countries because these countries are the repository of these resources. The conditions for transfer have never been more propitious: thanks to information technology and the news media, people in these countries feel more connected to events in the other parts of the world than in the past, as the outpouring of financial and emotional support for the victims of the tsunami in Asia suggests. Moreover, there is unprecedented interest in sustainability issues in these countries (Sachs 2004). The stakeholders in sustainable development may need to capitalize on this unique opportunity with the message that sustainability can promote cooperation and advance harmony across countries (Jha 2005).

Our results suggest that a temporal perspective is important to understanding the effect of population growth and human development on deforestation in developing countries. High population growth and low human development may cause high rates of deforestation, but increase in human development may reduce deforestation despite high population growth. The decrease, however, may vary across countries because of economic policies. Policy-induced deforestation may be easier to fix than deforestation caused by human development. Knowledge of conservation may correct policy aberrations in the countries that are ahead in human development, but financial and intellectual resources will be needed to advance conservation goals in the regions where the pressure on forests to provide basic needs is high. Popular interest in sustainability in developed countries provides challenge and opportunity for the transfer of these resources to the regions that have human development constraints.

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