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The Role of Education in Neotropical Deforestation: Household Evidence from Amerindians in Honduras

Ricardo Godoy,[1] Stephen Groff,[2] and Kathleen O'Neill[3]

A survey of 101 Tawahka Amerindian households in the Honduran rain forest examined the effects of schooling on the clearance of old-growth rain forest. The results of tobit, ordinary least square, probit, and median regressions suggest that: (i) each additional year of education lowers the probability of cutting old-growth rain forest by about 4% and reduces the area cut by 0.06 halfamily each year, and (ii) the effect of education on deforestation is non-linear. With up to 2 years of schooling forest clearance declines; with between 2 and 4 years of schooling, clearance increases, but beyond 4 years education once again seems to curb deforestation. Even a little education curbs forest clearance because it is easier for individuals to acquire information about new farm technologies from outsiders in order to intensify term production by river banks. Estimates of the social rate of return to education for indigenous populations of Latin American have been shown to be high. We suggest that these rates of return may need reappraisal for Amerindians in the rain forest to take into account the positive and negative environmental externalities of education.

KEY WORDS: education; deforestation; Tawahka; externality; Honduras.

INTRODUCTION

Since the early 1970s, researchers have been studying the causes of neotropical deforestation, but to date they have paid scant attention to the role education might play in curbing the clearance of old-growth rain forest

[1]Department of Anthropology, Brandeis University, Waltham, Massachusetts 02454-9110.
[2]Asian Development Bank, P.O. Box 789, Manila 0908, Philippines.
[3]Department of Government, Harvard University, Cambridge, Massachusetts.

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(Gómez-Pompa *et al.*, 1972; Denevan, 1973). Using information from rural households in India, some researchers have said that schooling lowers the dependence of rural people on the forest by increasing their chances of earning income from jobs inside and outside the farm (Hedge *et al.*, 1996). Using information from many nations in Africa, researchers have found that rates of enrollment in primary school reduce the area of wilderness lost (Cleaver and Schreiber, 1991). So far attempts to explain the paths linking formal education and conservation have relied on narratives rather than on theory or on quantitative evidence (Godoy, 1994). We know of no study focused on why and how schooling could affect conservation.

In this article we take a first step in filling the gap by presenting a model about the direct and the indirect effects of schooling on tropical deforestation. We then test the idea that formal education lowers deforestation in a non-linear way by using a household survey from the Tawahka Amerindians of Honduras. We focus on the clearance of old-growth rain forest because it contains more biological diversity than secondary-growth forest (Frumhoff, 1995; Lawrence *et al.*, 1995; Saldarriaga *et al.*, 1985), although secondary-growth forests can also be rich in species (Denevan, 1992; Finegan, 1996; Silver *et al.*, 1996). Though we use old-growth forest, the model also applies to secondary-growth forest.

We stress the role of education because theory and empirical evidence suggests schooling may affect conservation, though the direction and the magnitude of the effect remain unclear. Although much theoretical and empirical work shows that education improves agricultural productivity and labor migration, the same cannot be said about the role of education in conservation. It is precisely because theory suggests that schooling can have ambiguous effects on forest clearance that we decided to undertake the empirical analysis discussed in this article. As we shall see in the concluding section, comparative evidence from several Amerindian societies in tropical Latin America suggests that education can both hurt and help conservation.

THE MODEL

We hypothesize that even when we control for household and village attributes, schooling will lower a household's propensity to clear old-growth forest owing to direct and to indirect effects. The marginal effect of schooling by itself on the clearance of old-growth forest will be negative after we measure and control for other variables, such as income, age, and proximity to towns.

Direct Effects

Schooling and the ability to speak the national language should increase the political leverage of indigenous people, allowing them to better defend their interests against encroachers (Schmink, 1992). If education enhances rural people's ability to deal with change, as Schultz (1975) and recent studies confirm (Foster and Rozensweig, 1996), then education should help dwellers of the rain forest cope with the depletion of forest resources by increasing their ability to domesticate feral forest goods, change cultural norms, and develop new institutions to reverse environmental degradation (Murray, 1987; Robinson and Redford, 1991).

Indirect Effects

Besides these direct ways of improving the conservation of rain forests, rural schooling could reduce people's dependence on the forest through indirect channels. Schooling could increase the ability of foragers to leave the countryside, encourage them to adopt new farm technologies, use old agricultural technologies better, and reduce their family size, each of which will ease pressure on the forest. Below we discuss some of these indirect paths.

Migration

Researchers have shown that rural education encourages migration to other villages or to cities (Barros, 1978; Kowalewski and Saindon, 1992; Robertson, 1977; Schultz, 1988), though the link between schooling and migration may often be weak (Stark, 1991; Varavarn, 1978). We still do not understand how rural to urban migration affects people's use of the rain forest. In the immediate future, migration to the city induced by education should reduce pressure on the rain forest because it reduces the size of the rural population and thus reduces the labor available for agriculture, including clearing. Migration may also reduce the welfare of villagers who stay if migrants take capital with them and become net receivers of remittances from their rural kin (Schuh, 1982). In the medium to distant future, rural to urban migration by villagers with more education raises rural income through net remittances of cash and goods from the city to the countryside. These remittances probably increase the consumption of forest goods such as timber used to build more durable and prestigious houses (Lipton, 1982), lower demand for forest goods facing competition from cheaper industrial substitutes, pay for the education of younger siblings (Pomponio and Lancy, 1986), and may allow for innovations in farming (Stark, 1991). In the long run, permanent migration to cities should reduce local demand for forest goods.

Agricultural Technology

Schooling, and to a lesser extent literacy, produces cognitive skills which make it easier for villagers to seek, find, and use information about agricultural innovations (Phillips, 1994). Even without new agricultural technologies, education helps farmers get more from their inputs (Azhar, 1991), cope better with political and legal problems (Goody, 1986), manage their farms better, particularly if the farm produces many outputs (Pudasaini, 1983), get higher prices for their goods, and pay lower prices for their inputs (Jamison and Lau, 1982). In the short to medium term, agricultural modernization could add pressure on the forest (Angelsen and Kaimowitz, 1997; Hertel and Preckel, 1990), but in the long run it encourages out-migration, industrialization, and, in so doing, helps the conservation of rain forests (Southgate, 1991; Southgate and Whitaker, 1992).

To test the idea that education lowers tropical deforestation in a nonlinear way, we conducted a household survey among the Tawahka Amerindians of Honduras in 1995. The study was part of a two-and-a-half-year study to examine the effects of markets on indigenous people's use of natural resources. We chose the Tawahka because they displayed variance in integration to the market and in educational level and because they had access to old and secondary-growth rain forest. The model could have been tested in any other rain forest society with access to old-growth rain forest and with sufficient variance in educational attainment. As discussed in the conclusion, the findings from the Tawahka are similar to the findings from a study of three Amerindian societies in the Bolivian rain forest.

THE PEOPLE

The Tawahka live in five settlements along the Patuca river in the rain forest of eastern Honduras. About half of the Tawahka live in the village of Krausirpe, which lies farther downriver (and closer to the market town of Wampusirpe) than the other four villages. In the early 1990s the Tawahka federation acquired legal status as a reserve and resettled about eight households living outside the Tawahka territory inside the reserve.

In Table I we summarize demographic and socioeconomic information from the survey we conducted in 1995. The average Tawahka household has lived for about 20 years in its present residence. Average age of household heads is 38.7 years old; households contain about eight people, half of them adults (evenly split between men and women) or people over the age of 12.

Tawahka subsistence centers on extensive swidden cultivation and on more intensive farming by river banks. The Tawahka plant cacao and beans

Table I. Socioeconomic Characteristics of Tawahka Households

	Variable	Units	No.	Year	Average	Standard deviation
1.	Demography					
	Residence duration	years	100	1995	20.0	15.0
	Age of hh head	years	101	1995	38.7	14.1
	Hh size total	people	101	1995	7.7	3.3
2.	Education					
	All men	max grade	394	1995	2.2	2.4
	All women	max grade	389	1995	1.7	2.2
	Total	max grade	783	1995	2.0	2.3
	Male hh head	max grade	86	1995	2.6	2.4
	Female hh head	max grade	15	1995	1.4	1.9
	Either hh head	max grade	101	1995	2.4	2.4
	Spanish	fluency (%)	101	1995	61	48
3.	Agriculture					
	Adopters of new technologies					
	Herbicides	percent	99	1994	43	49
	Rice	percent	94	1994	70	45
	Beans	percent	80	1994	88	31
	Cacao	percent	91	1994	37	48
	Rice sold (%)	percent	91	1994	7	12
	Beans sold (%)	percent	80	1994	8	14
	Harvest loss (%)[a]					
	Beans	harvest (%)	82	1994	32	27
	Rice	harvest (%)	93	1994	29	25
	Cacao	harvest (%)	46	1994	55	28

[a]Loss = loss/(loss + harvest).

in the most fertile plots by river banks and other perennials and annuals, such as maize and rice, in upland plots cut from old-growth rain forest or cut from forests in secondary growth. Old-growth rain forests away from the village are open for any villager to use, but prime plots by the river seem to be inherited more and more along the male line as the people/land ratio increases. Many Tawahka use modern farm technologies: 37% of the households interviewed used hybrid seedlings of cacao and 43% used chemical herbicides in 1994; also about 75% of the households used improved varieties of beans and rice in 1994. The Tawahka we surveyed in 1994 reported losing about 30% of their potential bean and rice harvest and 55% of their cacao harvest to pests, diseases, and to bad weather.

Although Tawahka use new farm technologies, they sell only 7–8% of their rice or bean harvest. In 1994, households earned the equivalent of $106 dollars from the sale of rice, beans, and cacao. The average Tawahka household controlled 20.8 hectares of land, divided between fields in use, which account for 12% of total land holdings, and fallow plots in river banks (27%) and in upland secondary-growth forests (61%).

Besides practicing swidden farming the Tawahka also forage for wild plants, hunt, and work outside their villages panning gold, making dugout

Table II. Characteristics of Plots from Old-Growth Forest and Cutters, 1995

Variable	No.	Percent	Avg.	SD
Number of hh cutters	50			
All households (%)		49		
No. fields/household	53		1.1	.45
Hectares/field	54		.96	.72
Distance village to house in:				
Minutes	53		29.9	16.90
Kilometers	50		1.7	1.00
New plots next to owner's old plots		35.5		
Main crops sown	53			
Rice		85		
Maize		11		
Other		4		
Total no. Adult person-days to clear plot			18.6	22.9
Other uses (%)				
Plan to put cattle	53	6		
Used timber	50	32		
Used firewood	50	86		
Reasons for not cutting more old growth forest (n = 101)				
No time		36		
No need		10		
Had fallow lands		9		
Not enough labor help		12		
Not enough money to hire workers		6		
Not enough seed		7		
Illness		4		
Protect forest		8		
Other		8		

canoes for sale, or helping in cattle ranches. Within the reserve, a few Tawahka also work for the government as teachers.

Forty-nine percent of the Tawahka households cut old-growth rain forest to plant crops in 1995 (Table II). Households typically cut only one field from old-growth rain forest, though four households (8% of the population of cutters) cleared more than one field. On average fields made from old-growth rain forest measure 0.96 ha, take 29.9 min to reach by foot from the village, lie 1.7 km as the crow flies from the village, and, in about a third of the cases, lie next to another field belonging to the same farmer. It took one adult 18.6 days to cut and to burn an average plot from old-growth rain forest; these fields are cleared primarily for rice cultivation. As a by-product of forest clearance 86% of the households also got firewood and 32% got timber; 6% of the population planned to raise cattle on the plots.

When asked why they did not make their fields from old-growth rain forest larger, the Tawahka mentioned shortage of time (often from wage labor) (36%), lack of need owing in part to the availability of forest fallow (19%), insufficient labor help (12%), shortage of cash to hire workers (6%), lack of seeds (7%), and illness (4%).

SCHOOLING AMONG THE TAWAHKA

Schools were first set up in Tawahka territory in 1910 (Landero, 1935) but they were discontinued after only a few years. The oldest surviving school, dating back to 1958, is in the village of Krausirpe; it covers only the first six grades (Cruz and Benitez, 1994). Other Tawahka villages had to send their children to Krausirpe or to the Miskito town of Wampusirpe downriver for primary or for middle school. Since eastern Honduras still lacks high schools, parents must send their children to the capital or to cities in northern Honduras for higher education.

The expansion of education among the Tawahka dates only to the mid-1980s. During the conflict with Nicaragua a few Tawahka received training as paramedics, often in the Contra army. Development organizations working with Nicaraguan refugees along the Honduran border helped finance the training of the first group of middle-school graduates; by the early 1990s about ten Tawahka had finished middle-school. In the past 5 years, with backing from the central government and nongovernmental organizations, the Tawahka federation has set up primary schools in other villages besides Krausirpe and has started to train and to use Tawahka bilingual teachers to run the schools. At present, about 23 young Tawahka men and women selected through competitive exams are receiving training in the city of Tegucigalpa to become bilingual school teachers back in their homeland.

Formal education among the Tawahka is low and skewed toward males (Table I). The average Tawahka has about 2 years of schooling. Males have more schooling (2.2 years) than females (1.7 years); male heads of households have nearly twice as many years of schooling (2.6) as female heads of households (1.4). In 1996 the first Tawahka graduated from high school.

However, even this low level of education seems to affect the choices Tawahka make between labor and leisure and between different economic occupations. In Table III, we present preliminary information on time allocation for 100 Tawahka adults from over 30 households from the villages of Krausirpe and Yapuwás. The information comes from random spot observations of people's activity from dawn to dusk during 8 months of 1995 and is broken down by the educational level of the subject. The information presented in Table III suggests that education lowers the share of time Tawahka spend resting but increases the share of time they spend farming. People with no education spent 23.57% of the day resting, but people with at least 1 year of education spent only 18% of their time in leisure. People without education spent 5.65% of their time farming; the share of time spent farming rose to 10% when people reached at least 4 years of schooling.

Table III. Time Allocation of Tawahka Adults by Educational Level (Percent of Time in Different Activities from Spot Observations)

Activity	Number of observations	Years of education 0	1–3	4+
Social/personal[a]	2119	31.57	36.75	28.44
Subsistence [b]	2233	33.25	32.20	36.68
Agriculture [c]	490	5.65	6.05	10.54
Leisure[d]	1307	23.57	18.52	18.25
Other[e]	387	5.76	6.14	5.81
Total	6536	100.00	100.00	100.00

[a]Social/personal: visiting, playing, socializing, speaking, praying, dressing, eating, grooming, reading, writing, ill.
[b]Subsistence/manufacturing/foraging: childcare, cooking, food preparation, wage labor, repair, sawing, drying, fishing, gathering, hunting.
[c]Agriculture: animal husbandry, land preparation, harvesting, planting, weeding.
[d]Leisure: resting, static, idle.
[e]All other activities not captured in *a–d*.

Table IV presents the results of bivariate regressions of education as an explanatory variable against selected dependent variables. Because we cannot control for reverse causality or for omitted variable bias in bivariate analysis, we should read the results of Table IV with caution. Contrary to what we might have expected, the results show that education lowers the probabilities of working outside the farm or of working in non-farm jobs inside the village. These results should be read with care because they only apply to the month of May 1995. Tawahka with more education are less likely to pan gold, to run a business, or to earn income from rents, but are more likely to teach.

Education seems to be associated with a switch from subsistence to cash cropping, from the cultivation of rice in old-growth forest to the cultivation of cash crops, such as cacao and beans, on fertile river banks. Education is positively associated with the number of hybrid seedlings of cacao acquired in 1994 and 1995, with cacao production, and with the number of immature cacao trees owned by the household. Tawahka with more education also lost less of their cacao harvest to pests, diseases, and to natural disasters. Beans echo the story of cacao. Education is associated with greater bean yields and with lower losses of the bean harvest.

Although education seems to increase the output of crops sown on fertile river banks, it seems to reduce the productivity and investments in rice, typically grown in old-growth rain forest away from the river. Table IV shows that education is associated with lower yields of rice, greater losses of rice to pest and diseases, and with lower use of chemical herbicides. In Table IV we also see that heads of households with more educa-

Table IV. Bivariate Regressions of Selected Socioeconomic Dependent Variables on Education of Household Head

Dependent variable	coef.	SE	t	P > | t |	R^2	n
Labor						
Non-farm income[a]	−0.01	0.01	−0.82	0.412	.0077	90
Cacao						
Nonbearing trees	9.59	9.90	0.96	0.335	.0013	91
Seedlings, 1994	7.51	6.45	1.16	0.240	.015	91
Seedlings, 1995	1.36	4.07	0.33	0.730	.001	91
Production (lb), 1994	6.12	5.60	1.09	0.278	.011	101
Harvest loss (%)[b]	−0.06	0.12	−0.51	0.610	.006	40
Beans						
Yields,[c] 1994	0.19	0.26	0.71	0.479	.009	98
Yields,[c] 1995	0.02	0.17	0.16	0.869	.0003	81
Harvest loss (%)[b]	−0.18	0.20	−0.89	0.372	.010	80
Rice						
Yields,[c] 1994	−0.02	0.21	−0.11	0.905	.0002	96
Harvest loss (%)[b]	0.03	0.05	0.05	0.554	.0040	90
Herbicide (bottles)	−0.03	0.07	−0.50	0.610	.005	98
Labor[d]						
Clearing old-growth forest	−0.96	1.42	−0.68	0.490	.009	53
Clearing secondary growth forest	−0.47	0.46	−1.01	0.310	.008	116
Fields in which herbicide used	−1.61	1.63	−0.59	0.330	.061	17
Illness during bean harvest[e]						
1995 harvest	0.08	0.11	0.71	0.470	.0007	769
1994 harvest	0.20	0.12	1.65	0.099	.0036	751

[a]Share of cash income earned in May 1995, from gold panning, rental, wage labor, and business.
[b]Loss = loss/harvest.
[c]*Quintales/tarea*, 1 *quintal* = 100 pounds, 4 *tareas* = 1 hectare.
[d]Adult person-days.
[e]Includes all people over the age of 12 who were too ill to work during the bean harvest.

tion invest less time clearing old-growth and secondary-growth forest and weeding fields in which they had used chemical herbicides.

Last, the information in Table IV suggests that education is associated with greater self-reported illness. The finding supports many studies in rural areas of other poor countries which show that people's threshold for reporting illness falls as income and education rise (Murray and Chen, 1992). With more education and with higher income people take more time off when ill. In a multivariate analysis of four Amerindians societies, which included the Tawahka and three societies from Bolivia, we found a positive relation between days lost to work from illness and educational attainment. We think that education makes people more aware of symptoms and diseases and therefore makes them more likely to report illness.

In sum, the information from Tables III and IV suggests that with greater education the Tawahka reduce the time they devote to leisure, the effort they put into farming rice in the rain forest, and the amount of work they do outside of agriculture. Education seems to increase the effort they put into farming cash crops sown in the most fertile lands by the river, which implies less clearance of old-growth rain forest.

Many researchers have found that education helps to increase farm output and to facilitate innovations in farming, but only after farmers finish at least 4 years of school, the minimum needed to keep skills for use later in life (Jamison *et al.*, 1982; Phillips and Marble, 1986). Among the Tawahka, education seems to yield dividends even below 4 years of schooling for at least three possible reasons.

First, the Tawahka may have relatively good education. As Landero's (1935) ethnography shows, missionaries put committed teachers in the Tawahka territory early this century. Since then the Tawahka federation has fought and won the battle to hire bilingual Tawahka teachers rather than outsiders. Tawahka bilingual village teachers do not miss school as much as outside teachers because social ties and farm chores anchor them to the villages where they live and work. Non-Tawahka teachers leave the area more frequently to buy supplies, to visit relatives, or to do administrative tasks in the town of Wampusirpe.

Second, even a little education gives Tawahka confidence in their ability to deal with outsiders, particularly Miskito extension agents from Wampusirpe who distribute hybrid seedlings of cacao, or riverine Spanish-speaking traders from western Honduras who sell improved grain seeds and chemicals for farming. Even if they do not learn how to read or write well after a brief stint of only one or two years in school, Tawahka with some schooling learn the interpersonal skills and gain the confidence needed to deal with outsiders. These skills make it easier for them to approach extension agents or traders to get information about new farm technologies, medicines, or industrial goods. The skills also make it easier for them to understand the instruction for the use of new goods. Educated Tawahka seem to be less shy about attending village meetings called by outsiders to discuss topics such as the dangers of herbicide use, the appropriate planting space for hybrid seedlings of cacao, or new training opportunities outside the Tawahka territory. After Tawahka adopt cacao, they drift toward riverine agriculture provided they or their families have access to prime riverine plots; cacao cultivation absorbs much household labor and keeps people with access to riverine lands from cutting the rain forest for swidden farming far from the river.

Last, in a poor and uneducated indigenous population such as the Tawahka even a little education confers large economic advantages on the recipients. Those with even a little schooling stand out from the rest and soon gain control of political posts in the federation. Outside institutions seek them out for training, workshops, conferences, and the like. These

Tawahka soon find their time filled with trips outside their reserve and have less time to devote to routine chores in the farm.

THE HOUSEHOLD SURVEY AND PRELIMINARY ANALYSIS OF THE INFORMATION IN THE FIELD

We conducted the household survey between June and August 1995, with a sample of 101 Tawahka households, or 88%, of the total Tawahka population. Of the 14 households we did not interview, four lived outside the reserve, three did not want to take part in the study, and seven were missed, probably because they were panning gold outside their villages. We did not try to interview Tawahkas who were outside their villages at the time of field work.

The interviews were led by a team of Tawahka and university students, with the Tawahka helping to translate questions when we interviewed monolingual speakers of Tawahka or of Miskito. The Tawahka helped to clarify points before entering the information into a lap-top computer. Having Tawahka do the interviews enhanced the accuracy of the information collected. While one member of the team asked a question the other wrote the answer; Tawahka and students alternated in these roles. As the study of forest clearance was part of a longer, two-and-a-half-year study investigating the effects of markets on indigenous people's use of natural resources, surveyors were able to draw on the ethnographic knowledge and on the logistical support of resident researchers.

We measured the perimeter of each field cut from old-growth forest with a hip chain and a compass and entered the information in the computer, which estimated the area of the parcel in hectares and the measurement error, defined as the gap between the starting and the ending points. Fields were measured again if closure errors were over 5% of the perimeter length.

Surveyors entered information from the interviews and field measurements in a computer in the field shortly after the interviews. Poor field measurements and ambiguous answers were clarified on the spot by asking Tawahka surveyors for clarification or by revisiting the people who had supplied the information.

In January and in November 1996, we returned to the Tawahka territory to discuss the preliminary results of the analysis with the Tawahka. We asked them to interpret the sign of coefficients of explanatory variables from the regressions. For example, we asked questions such as, "Why do you think that people with more education cut less old-growth forest and use less herbicide? That is what we found from the survey we did last summer." The question would prompt a discussion among the Tawahka about the paths through which explanatory variables affected the clearance of old-growth forest.

THE ECONOMETRIC MODELS

We used four econometric models: (i) tobit, (ii) ordinary least square with Huber robust standard errors, (iii) median regression, and (iv) probit with Huber robust standard errors.

We used a tobit model because the dependent variable, area of old-growth rain forest cleared in 1995, was censored at zero; 50 households or 49% of the sample did not cut old-growth rain forest in 1994. We tested and rejected the assumption of constant variance of residuals for some explanatory variables (e.g., income).

To ensure the results of the analysis were not sensitive to the model used and were robust to unequal variance of error terms we also ran ordinary least squares with Huber robust standard errors and a median regression (Deaton, 1995). These problems, though they remain uncorrected, do not affect the consistency and the unbiasedness of the coefficients and their signs, which remain the focus of the study.

Last, we used a probit model with Huber robust standard errors because we wanted to identify the determinants of whether or not households cut old-growth rain forest, not just the determinants of the extent to which they deforest. As a check on the probit, we ran a logit. Since logit and probit regressions produced similar estimates, we report only the results of the probit model.

THE VARIABLES: DEFINITION, RATIONALE, MEASUREMENT, AND SUMMARY STATISTICS

Table V contains definition and summary statistics of the variables used in the analysis. Below we discuss the rationale and the measurement of the variables.

Dependent Variable

Researchers face difficulties identifying old-growth rain forests from very old fallow forests because the two types of forests can resemble each other in species composition (Bush and Colinvaux, 1994). The Tawahka sometimes disagreed on whether a field had been cleared from old-growth rain forest or from fallow forest. Ecologists use different criteria to identify an old-growth rain forest, including high density of large lianas (five indi-

Table V. Definition and Summary of Variables Used in Regressions

Name of variable	Definition	Year of estimate	No.	Avg.	SD
Dependent					
Area	ha of old-growth forest cut	1995	101	0.51	.76
Explanatory					
Income[a]	imputed farm income; 1000s *La*	1994	101	6.8	5.8
Residence	Household residence duration in village in years	1995	100	20	15.0
Housesize	adults and children	1995	101	7.7	3.3
Age	age in years of household head	1995	101	38.	14.1
Spanish[b]	fluency in Spanish; native tongue or proficient	1995	101	.61	.48
Education	max education household head	1995	101	2.4	2.4
Off-farm	share of cash income from nonfarm activities, May 1995	1995	90	.62	.41
Animals	number of pigs and cattle	1994	101	2.0	3.7
Herbicides	bottles of herbicides used; 5 bottles = 1 gallon	1994	99	1.0	1.8

[a]In 1994 1 US$ = 9.40 *Lempiras* (La).
[b]D = dummy. Name of dummy variable equals one.

viduals over 10 cm in diameter in 0.10 ha) (Gentry and Foster, 1991), presence of big tree species (over 60 cm in diameter at breast height), or canopy heterogeneity and crown size (Foster and Brokaw, 1985). Since we did the survey after the Tawahka had cleared their fields, we could not use the presence of plants to identify the type of forest they had cleared. Instead, we had to rely on the owner's own judgment of forest type. When Tawahka surveyors disagreed with the judgment of the owner, we relied on the consensus of Tawahka surveyors. We measured every field cut from old-growth rain forest and recorded the area in hectares.

What are the implications of classifying a field as having been cut from fallow forest when in fact it was cut from old-growth forest? Measurement errors in the dependent variable will have two consequences for the results of our study. First, they will increase the standard error of coefficients, lower the statistical significance of explanatory variables, but will not bias coefficients. With measurement errors in the dependent variable, explanatory variables such as education will have less statistical significance, making our conclusions more conservative. Since we sampled most of the Tawahka population, having large standard errors does not create problems of interpretation because the estimated coefficients can stand on their own. As a check, we ran the regressions discussed later with area of secondary-growth forest instead of area of old-growth forest and found similar results.

Second, errors in the dependent variable will lead us to overestimate the value of the positive environmental externality of education if we impute the value of nontimber forest goods removed from old-growth forests to fallow forests.

Explanatory Variables

Income

International comparisons show that the link between income and deforestation is nonlinear (Cropper and Griffiths, 1994). We used the imputed value of agricultural production to proxy for income. So defined, the variable income becomes synonymous with the gross value of farm production, and should not be taken as a proxy for cash income. We created the variable income by multiplying the quantity of the three chief crops—beans, rice, and cacao—harvested in 1994 times the village price for each of the crops. The variable income underestimates the value of agricultural production or total income because it leaves out other crops besides rice, beans, and cacao; it also leaves out income earned outside the farm. We included a square term for income earned outside the farm to capture nonlinearities. We suspect that just as income affects forest clearance, so too forest clearance could affect income. We did not find an instrumental variable to control for reverse causality when using income as an explanatory variable. Since the variable income is lagged in time, problems of reverse causality ought to be less severe, though still present.

Residence Duration

The number of years a household has lived in a village should proxy for more informal rights to property, greater knowledge of local ecology for farming, and should lower the amount of old-growth rain forest a household clears (Bedoya, 1995; Pichón, 1997).

Age of Household Head

Young heads of households need to clear forest for subsistence and to leave forest fallows as inheritance for their sons. As sons set up their own households and move out of their parent's quarters the need to clear old-growth rain forest should decline.

Household Size

Household size should be linked in a positive way to deforestation. Larger households demand more food and also supply more workers to clear the forest and to prepare the land for cultivation (Bilsborrow, 1992).

Education

For reasons discussed at the beginning of this article we think that education should lower deforestation in a nonlinear way. We equate education with the maximum educational attainment of the household head.

Large Domesticated Animals

The stock of large domesticated animals (e.g., cattle, pigs) should push households to clear more old-growth forest for at least two reasons. First, beyond a threshold of herd size people can no longer make use solely of the village grazing common and must clear forest for pasture. Second, households may need to expand clearance to produce crops to feed animals, particularly pigs.

Spanish

The direct effects of fluency in Spanish on deforestation are unclear, but the indirect effects are clearer because proficiency in spoken Spanish should allow Tawahka to get information about the use of new farm technologies and understand the instructions for their use from their purveyors, typically Spanish-speaking riverine traders from western Honduras who ply the waters of the Patuca river. Fluency in Spanish should also make it easier for Tawahka to find work with outside organizations and with nearby cattle ranchers. Since much of the education the Tawahka received in the past was in Spanish, we include Spanish to ensure the education variable does not simply mark language skills. We created a dummy variable to represent whether or not either of the household heads spoke Spanish proficiently.

Non-Farm Occupations

Households working in nonfarm jobs such as trading should depend less on the forest for their income and will consequently need to clear less forest. We estimated the share of cash income from non-farm jobs earned in May 1995. We limited questions on earnings in cash to the month before the interview to enhance the reliability of informant recall. May falls in the rainy season, a time when Tawahka stay in their villages to farm. Although the choice of May to measure off-farm income may underestimate true cash income, the bias should affect all households in the same way. Since May is a low point for off-farm income, the variation across households will also be less than typically seen and the variable may therefore produce weak statistical results.

Modern Agricultural Technology: Chemical Herbicides

The use of chemical herbicides increases crop yields and should lower the need to clear old-growth rain forest for farming (Ledec and Goodland, 1988; Moran, 1993). Fields cut from fallow forests require more weeding, making fields cut from old-growth forests more attractive because they require less weeding. Nevertheless, chemical herbicides lower the costs of weeding and, in so doing, provide an alternative to new cutting. We asked about the amount of chemical herbicides used in 1994. We also measured the yields of rice and beans and asked about the use of modern seed varieties. Since the use of information on yields and herbicides produced similar results, we opted to use only herbicides to conserve degrees of freedom. We did not use information on modern seed varieties to proxy for modern farm technologies owing to the difficulties of classifying plants as either modern or traditional varieties (Godoy *et al.*, 1996a).

To capture community fixed effects we include village dummies. Community fixed effects refers to characteristics of the village, such as distance, fertility, or precipitation. To facilitate reading the results we equate the name of dummy variables with one. For instance, the variable "Spanish" = 1 if either of the household heads was fluent in Spanish.

RESULTS

In Table VI we present the regression results. In the discussion below we stress the size and the economic significance of the coefficient on education and not the level of statistical significance because we sampled most (88%) of the Tawahka population. The estimated coefficients can stand on their own (McCloskey and Ziliak, 1996).

The results of the regressions show that education lowers the probabilities of clearing old-growth forest after controlling for village attributes and for many household and personal socioeconomic attributes (though not for personal fixed effects, such as motivation). Each additional year of

Table VI. Determinants of Clearance of Old-Growth Rain Forest

	Tobit		OLS[a]		Probit		Median	
Variable	Coef.	SE	Coef.	SE	Coef.[a]	SE	Coef.	SE
Income	.000	.000***	.000	.000**	.003	.000***	.000	.000
Income2	−5e-9	2e-9**	−2e-9	1e-9	−1e-8	3e-9***	−5e-10	2e-9
Residence	−.008	.015	−.001	.007	−.038	.017**	−.004	.010
Housesize	−.032	.054	−.006	.025	−.035	.055	−.005	.035
Age	.005	.013	.000	.005	.013	.014	−.002	.009
Education	−.066	.077	−.046	.032	−.132	.084	−.060	.051
Spanish	.139	.332	.044	.171	.446	.368	.249	.236
Off-farmY	−.560	.395	−.308	.211	−.387	.433	−.305	.283
Animals	.028	.049	.014	.026	.046	.057	.018	.035
Herbicides	−.048	.093	−.018	.042	−.182	.098*	−.052	.049
Number	88		88		88		88	
censored	44		not applicable		not applicable		not applicable	
uncensored	44		not applicable		not applicable		not applicable	
R^2	.14		.22		.34		.14	

[a]Huber robust standard errors. Dependent variable = area of old-growth forest cleared, 1995, in hectares. Three village dummies included.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table VII. Probability of Clearing Old-Growth Rain Forest at Different Educational Levels: Simulations Using Probit Model[a]

Years of education	Probability of clearing	Marginal probability of additional year
0	67.46	
1	62.56	4.90
2	57.45	5.11
2.49 = mean	54.89	2.56
3	52.21	2.68
4	46.92	5.29
5	41.70	5.22
6	36.61	5.09
7	31.75	4.86
8	27.19	4.56
9	22.98	4.21
10	19.16	3.82
11	15.75	3.41
12	12.77	2.98
Average		4.34

[a]All explanatory variables (except education) held constant at their mean value.

schooling reduces the area of old-growth rain forest cut by a household by about 0.06 ha. Since the average household typically cuts about 0.5 ha of old-growth rain forest each year, education reduces the amount of old-growth forest cut by households by 12% each year. We replaced the dependent variable by the area of fallow forest cut, and found similar results, suggesting that education lowers clearance irrespective of the type of forest.

Put in terms of the total area of wilderness lost by the Tawahka, each additional year of education reduces cuttings of old-growth rain forest by three hectares per year for the entire Tawahka population. Since the Tawahka reserve contains about 230,000 ha of old-growth rain forest (Herliby, 1993), education by itself will not have a significant short-term effect on the area of wilderness preserved, but it will produce positive environmental externalities, as discussed later.

Estimating the Probabilities of Cutting Old-Growth Rain Forest

We used a probit model to estimate the probability of cutting old-growth rain forest at different levels of education holding all other explanatory variables constant at their mean value (Table VII). There is a 67% probability that heads of households without education will cut old-growth rain forest. The probability drops to 54.89%, for household heads with 2.49 years of schooling (the sample mean), to 36.61% if they complete primary schooling, and to 12.77% if they graduate from high school. The marginal

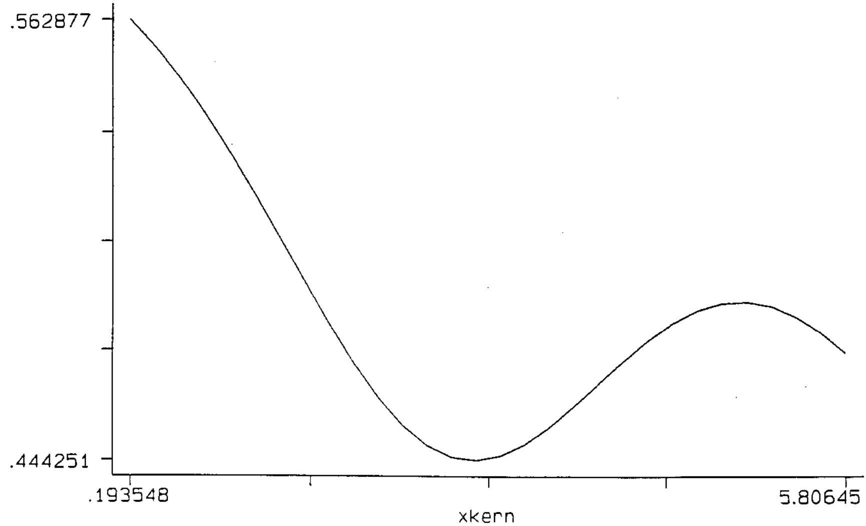

Fig. 1. Probability of clearing vs. H. household education.

effect of each additional year of education on forest clearance is greatest during the first six grades. Each year of primary school lowers the probability of clearing old-growth forest by about 5%; the marginal probabilities drop to 4% in middle school years, and to 3% in high school. Over all 12 years of schooling, each additional year of education lowers the probability of deforestation by an average of 4.34%.

Nonlinearities

We ran the models of Table VI with square and with cube terms for education and found that the sign of the square term was positive, but the sign of the cube term was negative, suggesting there may be two different types of thresholds at which education affects forest clearance.

To make it easier to visualize and identify thresholds, we ran separate bivariate kernel regressions of the probabilities of clearing old-growth forest (dependent variable) against the following explanatory variables: (i) the education of the household head, (ii) the average education of all household members, and (iii) the average education of all children in the household. A kernel regression predicts the value of Yi for observations close to X by taking a weighted average of Yis with the weights adding to one. A bandwidth parameter of 0.33 determines the weights; values of Yi close to x receive more weight than values of Yi far from X. With many observations

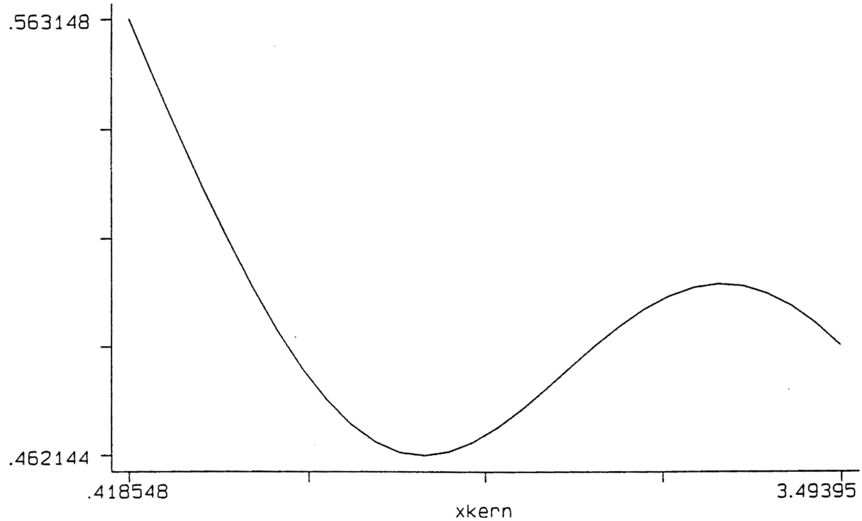

Fig. 2. Probability of clearing vs. average household education.

and with a small bandwidth, the predicted values at X are a good estimator of the conditional expectation of Y at X (Stock, 1995).

Figures 1–3 contain the results of the kernel regressions. The X axis shows years of schooling; the Y axis shows the conditional expectation of Yi for observations close to X. We estimated the expectation by weighing values of Yi close to X heavier than values of Yi far from X.

Figures 1 and 2 show that the education of the household head or the average education of all household members up to about 2 years of schooling produces a monotonic decrease in the probability of cutting old-growth forest. A little education lowers the probabilities of cutting old-growth rain forest, but household heads with 2–4 years of schooling seem to have higher probabilities of cutting old-growth rain forest than less educated household heads. Once households reach about 4 years of schooling, they seem to again cut less forest.

Although the effect of the household head's education and the average education of the household produces nonlinear effects on deforestation, the education of children produces a linear decline in deforestation (Fig. 3). Households that invest more in their children's education cut less old-growth rain forest than households with unschooled children. With children away in school, households have less hands to help with clearing.

It is unclear why education has two different thresholds, or why it causes deforestation to fall, rise, and then fall again. We hypothesize that education may have two different effects on deforestation: a productivity

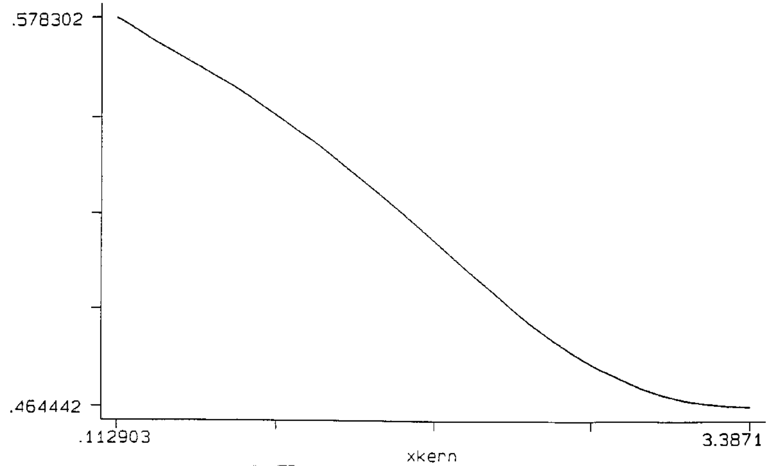

Fig. 3. Probability of clearing vs. average child education.

effect, leading to greater area devoted to all crops, and a risk diversification effect, as more educated farmers face greater opportunities to diversify the risk of crop failures by pursuing non-farm occupations. At low level of education, the productivity effect may overwhelm the risk-diversification effect, leading to greater clearing. But as people have more education, the risk diversification effect may overcome the productivity effect. Instead of diversifying the risk of failure of cacao or other cash crops by planting rice (which is intensive in labor and in land), more educated farmers may look to non-farm methods to earn income—teaching, owning a store, working for the Tawahka Federation, for instance.

The Environmental Externality of Education

Several scholars have recently shown that education among indigenous populations in Latin America increases their income and narrows income disparities with the nonindigenous population (Patrinos and Psacharopoulos, 1992; Patrinos, 1994; Patrinos *et al.*, 1994; Psacharopoulos *et al.*, 1994). In this section, we extend this line of thinking by showing that social returns to education of Amerindian rain forest dwellers may need reappraisal owing to the environmental externalities produced by education.

We first estimate the economic value of the rain forest by measuring the flow of only wild plants and game foraged by local populations. The results of about 24 case studies around the world suggest that the median financial value of both plants and animals removed from a tropical rain forest by local populations each year reaches $50/hectare (Godoy and Lubowski, 1992). Although we still do not have information on the value of nontimber forest goods extracted by the Tawahka, the comparable value for the Sumu Indians of neighboring Nicaragua is $35/hectare/year (Godoy *et al.*, 1995), suggesting that this part of Central America may be close to the world median. A reduction in the area of old-growth rain forest cut of 0.06 hectares brought about by one more year of education would therefore produce an estimated positive environmental externality of about $3 per hectare per family each year. Assuming a real discount rate of 10%, the net present value of the environmental externality would equal about $30 per hectare for each year of education of the household head.

The estimate is conservative because it leaves out other environmental goods and services produced by the rain forest (e.g., carbon sequestration). To correct for the undervaluation, we next estimate the value of other tangible and intangible benefits of the rain forest. Recent studies suggest that a hectare of old-growth rain forest yields yearly benefits equal to $441 per hectare from carbon sequestration, amenities, soil and water conservation, and biodiversity (but excluding the benefits produced by the flow of non-timber forest goods) (Panayotou and Ashton, 1995). Each additional year of schooling would therefore yield net benefits equal to $26.5 per year ($441/ha*0.06 ha). Assuming a real discount rate of 10% and biologically sustainable rates of extraction, the net present value could reach $265/hectare.

In sum, each additional year of schooling among the Tawahka could produce a positive environmental externality ranging from a conservative net present value of $30/hectare (if one values only the wild plants and game foraged by local populations) to about $295/hectare if, in addition, one adds the values of amenities and environmental services produced by the rain forest. The value is tentative because it is not corrected by negative environmental externalities of education, such as greater use of herbicide, commercial logging, and the like. Unfortunately, we do not have information to make these estimates.

To estimate the economic benefits of education to the Tawahka and to Honduras taking into account the positive environmental externality we regressed imputed agricultural income (dependent variable) against years of education, experience (defined as age minus years of schooling minus six), and sex. The results of the ordinary least square regression (not shown here) suggests that each additional year of schooling increases imputed farm income by about $30/year. Since the annual value of the externality calculated earlier ranges from $3 to $26.5 per year, leaving out the value of the externality would underestimate the annual return to an additional year of education by 10% (3/30) to 88% (26.5/30), depending on the method used to value the environmental externality.

CONCLUSIONS

How generalizable are the results from the Tawahka to other Amerindian populations? The question is important because, as mentioned, the model we have presented suggests that schooling could have positive effects on conservation.

We compared the data from the Tawahka against similar data from the Moje o, Yuracaré, and the Tsimane' Indians of the Bolivian rain forest. For the four cultures we ran a parsimonious tobit model of clearance of old-growth forest (dependent variable) against education, household size, residence duration, wealth, farm and wage income, illness, and a full set of village dummies. For the sake of brevity we do not report the regression results but simply note that the sign of the coefficient on education was negative for the Tawahka, Tsimane', and Moje o, but positive for the Yuracaré. In three of the four cultures education helped conservation and among the Tsimane' the coefficient on education was statistically significant at less than the 1% level. The comparative evidence then would appear to support the idea that schooling generally (but not always) helps to lower the area of forest cleared.

The analysis of the Tawahka information points to at least two further tentative conclusions. First, in indigenous populations of the rain forest with modest education, even a little schooling seems to produce quick and tangible economic benefits to households and to society. A small amount of education may do enough to allow households to pull apart from the rest and to do things which others may find difficult to do, such as adopt innovations in farming, deal with outsiders, or work outside the village. Elsewhere (Godoy *et al.*, 1996a) we discuss at length how schooling among the Tawahka helps them adopt new plant varieties and modern inputs for farming and allows them to intensify perennial production by river banks. Paradoxically, a little education among a largely uneducated group may at first also sharpen inequalities within the group, allowing the educated to control jobs, accumulate wealth, broker deals with outsiders, and, in so doing, wield greater power in the community. Some of the better educated Tawahka have taken the lead in the sale of precious timber species to outsiders and have been stopped only by the best trained leaders. As the rest of the Tawahka population gains more education they may be able to demand more accountability from their leaders. The effects on the environment of inequalities within indigenous populations brought about by education have yet to be researched.

Second, schooling probably produces positive as well as negative environmental externalities, even after we control for many different types of household and personal socioeconomic attributes. Depending on how one measures the economic value of the rain forest, the size of the positive externality for each additional year of schooling may range from a net present value of $30/hectare to $295/hectare; these estimates may be lower once we include the negative externalities of education, such as the use of chemicals in farming. The results of our study would suggest that orthodox estimates of the social rates of return to education in rain forest societies may not capture the true benefits of schooling to the nation if they leave out the tangible benefits and costs which schooling produces to conservation. If other studies confirm our tentative results that education produces net positive externalities, policymakers may have in education a new way of thinking about conservation.

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