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*Field Methods* 2003; 15; 289

DOI: 10.1177/1525822X03254847

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# Validity of Self-Reports to Measure Deforestation: Evidence from the Bolivian Lowlands

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*To assess rates of deforestation, researchers typically use questionnaires. But do questionnaires provide accurate information about the extent of forest clearance by households? In this article, the authors provide data on the amount of deforestation in a Tsimane' Amerindian village (Bolivia) and assess informant error by cross-checking three different assessments: (1) a direct physical measure by a research team of each plot cleared from the forest, (2) an estimate by the household head of the entire area cleared by his household during the year before the interview, and (3) an estimate by the plot owners of the area cleared of each plot he owns. Results show a high correlation between direct measures and estimates of areas provided by informants; plot owners provided more accurate information than heads of households.*

*Field Methods*, Vol. 15, No. 3, August 2003 289–304

DOI: 10.1177/1525822X03254847

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*Results suggest that asking Amerindians about the area of forest cleared will yield reliable estimates of deforestation.*

**Keywords:** *deforestation; indigenous people; informant accuracy; slash-and-burn agriculture; education; Tsimane' Amerindians; Bolivia*

Throughout the world, the area under forest cover has fallen sharply and continues to decline (Mathews 2000; Nepstad et al. 2001). The main causes of deforestation include slash-and-burn agriculture, logging, and cattle ranching (Hecht 1998; Demmer and Overman 1999). Indigenous people practice small-scale, slash-and-burn agriculture. Although some scholars think indigenous people do not deforest much (Pimentel and Heichel 1991; Myers 1992), others (Godoy 2001) say that indigenous people will contribute to higher levels of forest clearance in the future. Population pressure (Picchi 1991) and increasing integration into a market economy might induce households to expand the area of forest cleared (Simmons 1997; Godoy 2001). If the trend holds, the amount of forest cleared by indigenous people has to be measured, and the determinants of deforestation need to be analyzed before one can propose solutions. So far, there have been few attempts to measure the amount of forest cleared by indigenous people (Godoy et al. 1997).

Before estimating the area deforested, one must define deforestation and the type of forest it refers to. Deforestation is typically defined as the temporal or permanent clearance of forest vegetation (Lanly 1982; Grainger 1993), but researchers generally make no distinction between old-growth forest and fallow forest. *Fallow forest* refers to secondary forest (Myers 1992; Finegan 1996; Silver, Brown, and Lugo 1996; Smith et al. 1999). The earliest assessments of deforestation by the U.N. Food and Agricultural Organization (FAO) do not distinguish between fallow and old-growth forests (FAO 1993). Since indigenous people usually cultivate in a radius of 1–2 km from their residence, they tend to clear fallow forest instead of relocating close to old-growth forest. To measure total deforestation by indigenous people, we have to measure both old-growth and fallow forest cleared.

Since indigenous people live in limited, often circumscribed territory and move a great deal in search of fish, game, and farmlands (Reyes-García 2001), satellite imagery would provide only a rough estimate of deforested area. To get household measures of deforestation, we can draw on several approaches. First, we can get survey data on the amount of forest cleared by a household and on pertinent covariates likely to affect the amount of forest cleared. Before we can draw reliable inferences from survey data, we need to know the direction and magnitude of biases from measurement errors of informants (Bernard et al. 1984; Romney, Weller, and Batchelder 1986).

Second, we can make direct measurements of deforestation using a measuring tape and a compass. Direct measures provide more accurate estimates of deforestation but require more time. Last, we can calibrate the information from surveys with direct measures made in the field.

If we intend to calibrate the information on deforestation from surveys, we should also take into account factors likely to affect measurement errors in surveys. For example, formal education might affect the size and the direction of errors when estimating field size. People knowing the basics of arithmetic might make smaller errors when estimating the size of their fields because they are more adept at computations. Indigenous people are often illiterate, do not measure their plot, and are more likely to estimate the area they clear with error.

Here, we analyze data on the area of forest cleared by households in one village of Tsimane' Amerindians in the tropical rain forest of Bolivia. We distinguish between areas cleared from fallow forest and from old-growth forest and estimate how much error stems from informant answers in estimating (1) the area of forest cleared and (2) the type of forest (old growth or fallow) cleared. We do this by comparing the following three estimates: (1) the area cleared by the household as estimated by the household head, (2) the area cleared in each plot as estimated by the owner of the plot, and (3) the area of forest cleared by the household or the area of the plot as measured with a tape and a compass by a trained research team. This study builds on a previous study of error in estimation of field size in Honduras (Godoy et al. 1998) by focusing on different methods for judging accuracy. The previous study focused more on the socioeconomic covariates of error.

## THE TSIMANE'

The Tsimane' are a foraging and horticulturalist society of approximately seven thousand people living mostly along the Maniqui and Apere rivers in the department of Beni in the Bolivian lowlands. Ellis (1996), Chicchón (1992), Huanca (1999), and Reyes-García (2001) provided ethnographic descriptions of the Tsimane'.

The Tsimane' practice traditional slash-and-burn horticulture. Between June and September, they clear forests using simple tools. The type of crop they intend to plant affects the decision of how much forest to clear. When deciding whether and how much fallow forest to clear, the Tsimane' also take into account the size of the tree trunks rather than the number of years that have elapsed since the last cropping cycle. The Tsimane' do not generally measure plots. Once cleared, they plant their main staples—rice, maize, cas-

sava, and plantain—and crops of less importance (e.g., sugarcane, groundnuts, or sweet potatoes). After a short cultivation cycle of only one to two years, they abandon the plot to clear another plot. The abandoned field remains an important purveyor of game, fruits, and plants long after it has ceased to produce farm crops and has managed to produce many plants (e.g., shafts for arrows, citrus) (Huanca 1999). Once the plot is abandoned, forest vegetation takes over. Years later, it is sometimes hard to notice whether or not a forest patch had been previously cleared. During the past thirty years, under the influence of Protestant missionaries, the Tsimane' have progressively modified their settlement and migratory patterns, from extended families moving along the river to find farmland and game, to more sedentary settlements in small villages of ten to thirty households. Households in more sedentary villages find it increasingly necessary to clear fallow forest.

## METHOD

### Setting

Fieldwork took place in the Tsimane' village of Yaranda (15°16.369 S, 66°50.838 W) along the Maniqui River. We selected the village because it is representative of other Tsimane' communities in access, size, type of subsistence, and degree of integration to the market economy. People still have old-growth forest to clear within walking distance from their homes. The community has twenty-five households, a school, and two teachers, who cover grades one through five. The village lacks access by road. During the dry summer months, between June and November, people reach the nearest market town by walking for two days or by canoeing for three days. Walking is possible during the wet month, but people are reluctant to visit the market towns canoeing because of the difficulties of paddling upriver.

### Sample

The sample consists of twenty-five households and all the plots ( $n = 36$ ) they cleared during 1999.

### Education

Since educational level and skills in arithmetic might affect the error in estimation of field size, we also asked participants about the maximum education level they had reached. To measure skills in arithmetic, we gave a test in which we asked individuals four questions that required them to add, sub-

tract, multiply, and divide. We assigned one point to each correct answer; the total score could range from zero to four.

### Plot Measures

Our objective was to estimate and compare the size of plots cleared from old-growth forest or fallow forests using the following three methods.

*Method A: direct measure.* A non-Tsimane' researcher and an adult Tsimane' guide measured all the plots ( $n = 36$ ) in the community during one growing season (September and November 1999). To decide whether plots were from old-growth or fallow forests, we had a Tsimane' informant tell us the type of forest from which each plot had been cleared. When we arrived at a plot, we asked the Tsimane' informant to tell us the name of the person who had cleared the plot. We measured the plot sides with a measuring tape and the angles of the plots with a compass. We entered the information into a computer program that drew the field and calculated the surface area and the perimeter. We remeasured plots if the calculation error given by the computer program was more than 5% of the plot area. Since the measurement consisted of measuring the sides of the fields and the angles between sides, this could result in the perimeter not reaching closure. In that case, the computer program provided an estimate of the gap or open area of the perimeter. For the analysis, we used the direct measure of the plot by the research team as the most accurate estimate of the true area.

*Method B: interview of the household head.* In May 2000, about four months after having measured the field, we interviewed the male household heads ( $n = 24$ ) without referring to the information already gathered through method A. We asked the household heads to estimate the total area of forest they had cleared that year; we did not ask them about the area cleared for specific fields. We recorded the estimates in *tareas* (1 *tarea* = 0.1 ha), the unit of measure Tsimane' use to estimate area.

*Method C: interview of the plot owner.* A month later, in June, we conducted another interview with the person who had cleared the plot, and we did this for every plot measured with method A. To remind the plot cutter what plot we wanted him to estimate, we referred to the physical location of the plot and to the crop that he had planted on that plot at the beginning of the season. We interviewed any person (not just the household head) who had cleared a plot. For each of the plots measured with method A, we asked the person who had cleared the plot to tell us the type of forest cleared and to esti-

mate the surface of the plot cleared. In many cases, people did not estimate the surface in tareas but gave an estimate of the length of the field sides in meters. In that case, we assumed the fields were perfect rectangles and converted the meter data into tareas. We used methods B and C one month apart to avoid leaks of information among informants and to reduce possible confusion between the two questions.

## RESULTS AND DISCUSSION

### Summary Statistics

When we measured plots (method A), we asked the Tsimane' guide to decide whether the plot had been cleared from old-growth or fallow forest. When we interviewed the plot cutter (method C), we also asked the cutter whether the plot had been cleared from old-growth or fallow forest. The results show high correlation between what the plot cutter reported and what the Tsimane' guide had said; in only five out of the thirty-six plots did the plot cutter and the Tsimane' guide differ in their identification of forest type.

During 2000, the entire village cleared thirty-six plots covering an area of 15.36 ha. The average household had 1.5 plots. The mean area cleared per household was 0.694 ha, and mean plot area was 0.427 ha (see Table 1).

People cleared about the same number of fields from old-growth (nineteen) and from fallow forests (seventeen). The surface cleared from old-growth forest represented about two-thirds of the total area cleared (see Table 1). Plots cleared from old-growth forest were larger (0.52 ha/household) than those cleared from fallow forest (0.32 ha/household).

### Relation between Measured Area Cleared by Household and Estimate by Household Head

To estimate the total area of forest cleared by a household, we added the area cleared in each plot by the household as determined by the research team (method A). We regressed the values measured by the team against the area estimated by the household head. With perfect accuracy, we would expect a slope equal to 1. The regression yielded a slope of 0.51 ( $t = 3.56, p < .002, R^2 = .40$ ; see Figure 1), far from the expected value of 1. The results suggest that male heads of households (method B) provide inaccurate estimates of the total amount of area deforested by the household. Household heads underestimate the area of forest cleared. Later we explore possible causes of underestimation.

TABLE I  
Summary Statistics of Cleared Plots by Method of Estimation

Method	Forest Type (number of plots)		Total Area per Forest Type (ha)		Total Area (ha)	Area HH <sup>-1</sup> (ha)	Area Plot <sup>-1</sup> (ha)
	OGF	FF	OGF	FF			
	A	19	17	9.83			
B	NA	NA	NA	NA	13.13	0.597 ± 0.069	—
C	20	16	9.71	4.36	14.07	—	0.391 ± 0.041

NOTE: Method A = plot area measured by researcher's team; method B = household area cleared estimated by household head (HH); method C = plot area cleared estimated by plot owner; NA = not asked. Plot type refers to the forest type cleared for agriculture, either old-growth forest (OGF) or fallow forest (FF). Plot surface is given in tareas (1 tarea = 0.1 ha). Mean area cleared given per household (area HH<sup>-1</sup>) or per plot (area plot<sup>-1</sup>).

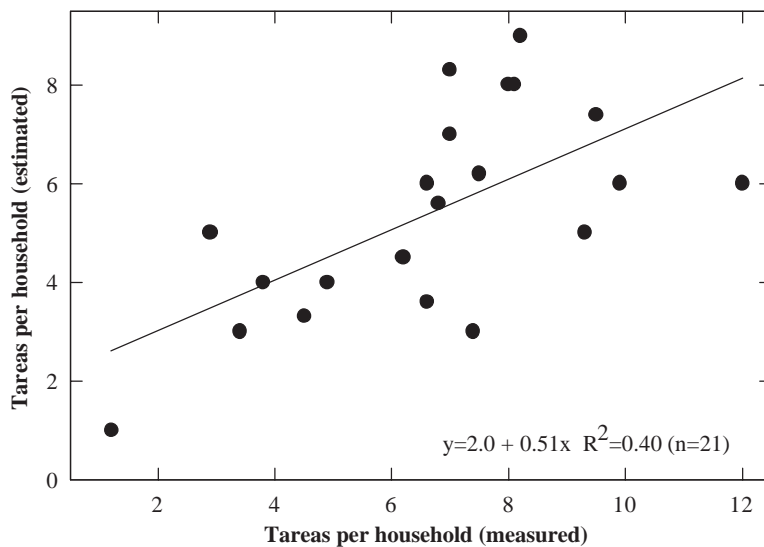
#### Relation between Measured Area of Plot and Estimate by Plot Owner

Because the household head provides a biased estimation of the forest area cleared by the household, we next compare the area measured of each plot with the estimation provided by the owner of the plot. We regressed the values measured by the researcher team against the estimate given by the plot owner. We found a slope of 0.84 ( $t = 8.60$ ,  $p < .0001$ ,  $R^2 = .68$ ; see Figure 2). We tested that the coefficient was equal to 1 and accepted the null hypothesis that the coefficient was equal to 1 at the 95% confidence interval ( $F = 3.55$ ;  $p < .0713$ ), suggesting that plot cutters provide accurate estimates of the size of their plots.

#### Relation between Measured Area Cleared by Household and Estimation Error by Household Head

Household heads may have underestimated the total forest area cleared by their household if they forgot about plots cleared by other members of their household. If true, we would expect to find a positive correlation between the error of estimation made by the household head and the actual area cleared per household as measured by the researcher team. Figure 3 shows the slope of the regression of estimation error made by the household head (dependent variable) and the area of forest actually cleared by the household. As the figure illustrates, we found a statistically significant positive correlation (slope = 0.49,  $t = 3.39$ ,  $p < .003$ ,  $R^2 = .38$ ). In Figure 3, points along the line  $y = 0$  imply small informant error. The pattern of Figure 3 suggests that household heads

FIGURE 1  
 Plot between the Estimates of Area Cleared by Households,  
 Given by Each Household Head, and the Actual Values of  
 Area Cleared of Households, Measured by an Independent Researcher



NOTE: Data are expressed in tareas (1 tarea = 0.1 ha;  $n = 21$ ).

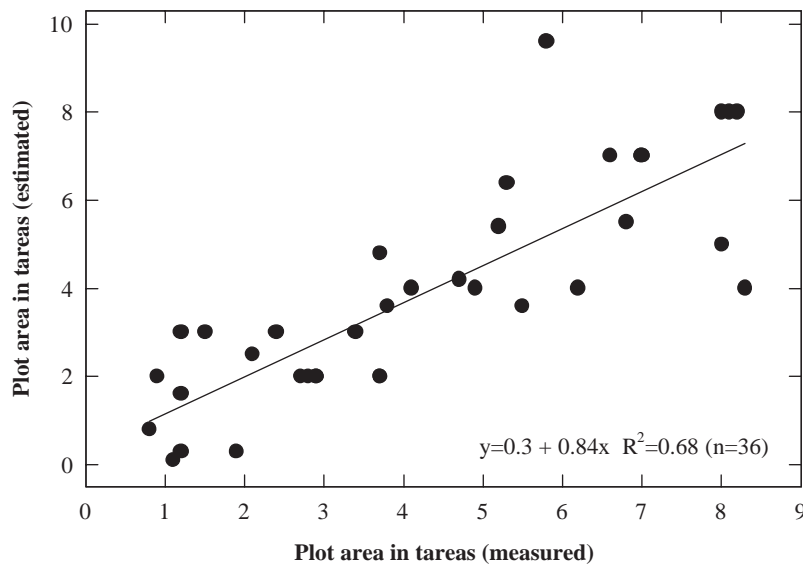
are more likely to provide faulty estimations when the true area cleared exceeds 4 tareas. In households with larger areas of cleared land, household heads are more likely to forget plots.

#### Relation between Measured Area of Plot and Estimation Error by Plot Owner

We regressed the error in estimation by the owner of the plot against the area measured by the research team (see Figure 4) and found no significant relation (coefficient = .08,  $t = 0.93$ ,  $p < .36$ ,  $R^2 = .02$ ); the slope was not significantly different from 0. The results suggest that the error in estimation by the owners of the plot is not related to the size of the plot.

We also expressed the error of estimation by plot owner as a percentage of the measured area of the plot (area estimated by plot owner minus area mea-

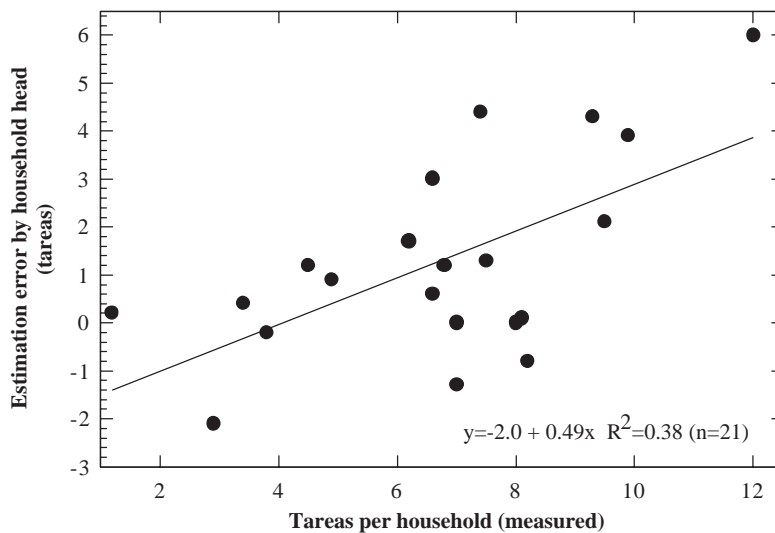
FIGURE 2  
Plot between the Estimates of Area Cleared of Plots,  
Given by Each Plot Owner, and Actual Values of Area Cleared  
of Plots, Measured by an Independent Researcher



NOTE: Data are expressed in tareas (1 tarea = 0.1 ha;  $n = 36$ ).

sured by the team divided by the area measured by the team). Because plot owners either overestimate or underestimate the size of their fields, the difference between the area measured by the researcher team and the estimate given by the plot owner can either be negative or positive; we therefore took the absolute values. We regressed the absolute values against the area measured by the research team (see Figure 5). We found a hyperbolic relation: For plots smaller than about 3 tareas, plot owners made an error that represented a high percentage of the plot area measured. This might be due to informants' using relatively coarse units of area in their responses no matter how large or small their plots were. Figure 2 shows that the error seemed to be rather constant across the range of field sizes. The heaping of the curve would

FIGURE 3  
 Plot between the Estimation Error by the Household Head  
 Minus the Estimate Given by the Household Head and the  
 Area Cleared of Households, Measured by an Independent Researcher



NOTE: Estimation error by the household head is the actual value of area cleared by the household (measured by an independent researcher). Data are expressed in tareas (1 tarea = 0.1 ha;  $n = 21$ ).

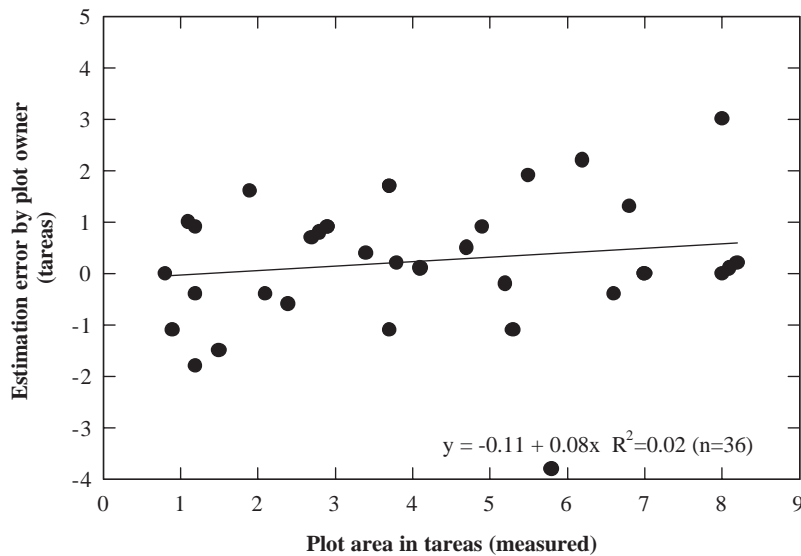
be explained by errors representing a large proportion of the field size in cases of small fields; the proportion decreases as field size increases.

Since plots from fallow forests were usually smaller (3.2 tareas) than plots from old-growth forests (5.2 tareas) (calculated from Table 1), the results are consistent with the fact that there was more error in the estimation of fallow forest (total of 5.53 ha cleared measured against 4.36 ha estimated; see Table 1) than in the estimation of old-growth forest (total of 9.83 ha cleared measured against 9.71 ha estimated; see Table 1).

#### Relation between Human Capital and Estimation Error by Plot Owner

We also estimated the effect of education on the error made by the plot owner. The Pearson correlation coefficients between error, school grades,

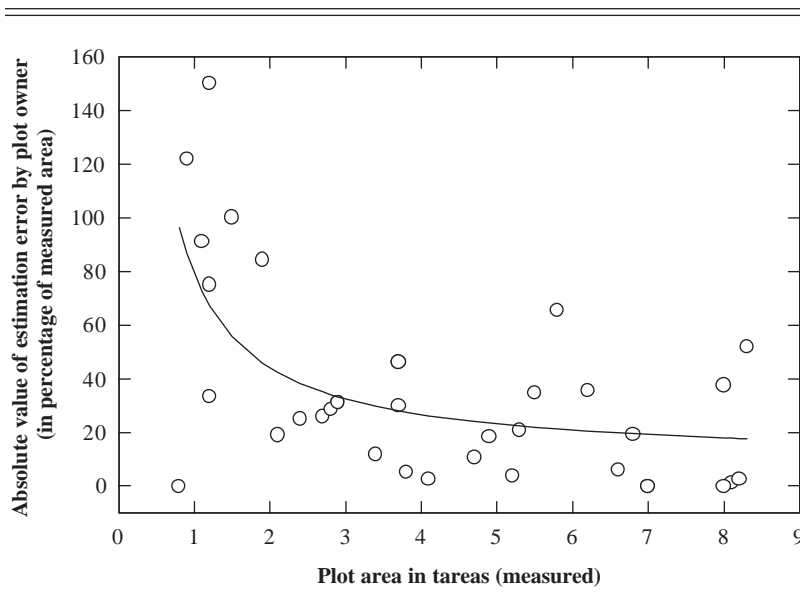
FIGURE 4  
Plot between the Estimation Error by Plot Owner  
Minus the Estimate Given by the Plot Owner and the Area  
Cleared of Plot, Measured by an Independent Researcher



NOTE: The estimation error by plot owner is the actual value measured of area cleared of plot (measured by an independent researcher). Data are expressed in tareas (1 tarea = 0.1 ha;  $n = 36$ ).

and arithmetic skills were  $-.35$  ( $p < .04$ ) and  $-.01$  ( $p < .94$ ). The Pearson correlation coefficient between school grades and arithmetic skill was  $.53$  ( $p < .0009$ ). Average number of school grades achieved by informant was  $2.2$  ( $SD = 2.6$ ), average mark on the arithmetic test was  $2.0$  ( $SD = 1.6$ ), and average error made (in tareas) was  $1.05$  ( $SD = 1.02$ ). We took the absolute values of the estimation error by the plot owner and ran a multiple regression with skills in arithmetic and the number of school grades completed by the informant as explanatory variables. We found that education bore a positive correlation with the error made by the plot owner. Having one more year of schooling correlated with lower estimation errors of  $0.21$  tareas ( $t = -2.77$ ,  $p < .001$ ; see Table 2). In contrast, an increase of one point in the arithmetic test had no significant effect on the estimation error ( $t = 1.41$ ,  $p < .17$ ).

FIGURE 5  
 Plot between the Absolute Values of Estimation Errors by  
 Plot Owner, Expressed as a Percentage of the Actual Plot Area  
 (Measured by an Independent Researcher), and the  
 Actual Value Measured of Area Cleared of Plot



NOTE:  $n = 36$ .

## CONCLUSION

The main empirical finding of this study is that informants generally give accurate estimates of the area of forest they clear, provided they are asked about the area they cleared on their own plots. In contrast, household heads asked to estimate the area cleared by their entire household underestimate the area cleared by their entire household. Household heads are likely to forget to include the area cleared by other members of their households. When they commit errors in estimations, informants tend to underestimate the true area cleared.

The educational level of the plot owner had an important weight on his estimation error, with more educated men making more accurate estimations. Previous studies show that among lowland Amerindians, schooling

TABLE 2  
Multiple Regression between the Absolute Value of Estimation Error by Plot Owner  
(dependent variable) and Skills in Arithmetic and Education of Participant

Variable	Coefficient	Standard Error	t	p
Arithmetic skill	0.17	0.12	1.41	.17
Education	-0.21	0.07	-2.77	.001
Constant	1.18	0.25	4.50	.0001

NOTE: Regression is ordinary least squares with robust standard errors;  $R^2 = .19$ .

correlates with lower rates of forest clearance (Godoy et al. 1997; Godoy and Contreras 2001). The results of this study suggest that education may allow people to estimate inputs more accurately and therefore gain greater efficiency in the use of forests resources.

Relative to the measured area, estimations errors were larger in smaller fields. As a consequence, people made larger errors when estimating the area cleared from fallow forest, since plots from this forest type were smaller than plots from old-growth forests. In contrast, people made accurate estimations of the area of old-growth forest cleared because they typically cleared larger plots from this forest type.

In sum, the analysis suggests that cross-sectional surveys will yield reliable estimates of area of old-growth and fallow forests cleared by indigenous people provided one asks plot owners about the area of forest they cleared. Asking household heads about the area cleared by the entire household will yield inaccurate information.

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