# Declining Use of Wild Resources by Indigenous Peoples of the Ecuadorian Amazon

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## Introduction

Harvesting of wild resources by forest-dwelling peoples, via hunting, fishing, timber harvesting and forest product collection, has been identified a major threat to biodiversity in many tropical forest ecosystems (Asner et al. 2005; Peres et al. 2006; Castello et al. 2013). However, these activities are often central to the livelihoods of the poor and isolated populations that live at forest frontiers (Brashares et al. 2011; Wunder et al. 2014). This conflict is particularly salient for indigenous peoples of the Amazon Basin who have harvested wild products for centuries, control large areas of forest, and have populations that are growing rapidly (McSweeney & Arps 2005; Nepstad et al. 2006; Wunder et al. 2014). The discussion of potential solutions to this conflict has generated a large literature (e.g., Redford & Sanderson 2000; Terborgh 2000), but this discussion has taken place largely in the absence of landscape-scale evidence on levels and trends of wild resource use (Peres et al. 2006; Wunder et al. 2014). This lacuna is the result of difficulties in conducting large-scale social and biological surveys in this context, the near-invisibility of small-scale wild product harvesting to remote-sensing methods (Peres et al. 2006), as well as enduring barriers between conservation science and the quantitative social sciences (Fox et al. 2006).

To provide new insight to these issues, we draw on a unique dataset that captures changes in wild resource use by indigenous peoples of the Northern Ecuadorian Amazon (NEA) across 480 households, 32 communities, 5 ethnicities, an 11 year time period, and low to moderate connections to external markets. This effort expands on previous studies which have primarily investigated indigenous resource use via cross-sectional surveys (e.g., Brashares et al. 2011; Wunder et al. 2014) or small longitudinal samples (e.g., Vickers 1991; Gill et al. 2012) (for a key exception see Godoy et al. 2010). The NEA is of particular interest for these issues as the home of a large and growing indigenous population (Bremner et al. 2009), as well as the center of Amazonian biodiversity for many taxa and the location of high-profile conflicts between biodiversity conservation and resource use (Finer et al. 2008). We first use this dataset to describe various dimensions of wild resource use by this population, including hunting, fishing, timber harvesting and forest product collection. This effort reveals that the population is highly dependent on wild resources, but that this dependence has consistently declined over time across resource types and ethnicities. This decline has occurred in the absence of landscape-level environmental change, during a period of improving human well-being, and while various measures of resource quality have improved or remained stable, suggesting that declining dependence is not driven by resource quality. Small-scale timber harvesting is the primary exception to both of these findings.

Building on this descriptive analysis, we subsequently use multilevel regression models to investigate the social and economic predictors of wild resource use across time. This analysis reveals that ethnicity, demographic characteristics, wealth, livelihood diversification, participation in conservation programs, and exposure to external markets are all important predictors of resource use but in ways that vary distinctly across resource types. However these factors *cannot* fully account for the substantial declines in resource use across time, suggesting that regional-scale patterns of social and economic change, including urbanization and the expansion of government services and infrastructure, are driving these changes. The implication of these findings for conservation practitioners is that indigenous wild resource use can decline substantially even in the absence of successful conservation interventions, driven by large-scale processes of modernization affecting previously-remote parts of the world (Browder 1997; Espinosa 2008).

## Methods

### *Study Area*

The NEA is located at the western periphery of the Amazon Basin (Fig. 1) and overlaps the center of Amazonian species richness for amphibians, birds, mammals and vascular plants, marking it a globally important region for biodiversity conservation (Finer et al. 2008). The region has been inhabited for millennia by Amerindian indigenous peoples, but its current large-scale environmental transformation began only in the 1970s with the initiation of oil exploration. Road construction by the oil industry enabled large-scale agricultural colonization from outside the region and was facilitated by government land tenure policies (Bilsborrow et al. 2004). These processes have transformed the area between Coca and Lago Agrio (Fig. 1), where soils are productive for agriculture, into an urbanizing agricultural hinterland with only remnant forests, while colonization and oil extraction continue to penetrate into previously remote areas (Holland et al. 2014). Indicative of this ongoing transformation, the urban population of Sucumbíos and Orellana provinces, which overlap the study area, increased from 76 thousand to 129 thousand between 2001 and 2010 (INEC 2014).

These processes have radically transformed the regional context for five resident and culturally distinct indigenous groups, the Cofán, Kichwa, Shuar, Secoya and Waorani, via territorial displacement and circumscription as well as increased contact with the outside world (Lu & Bilsborrow 2011). Despite these changes, all five groups, particularly the Waorani and Cofán, have retained a significant degree of spatial, economic and cultural isolation from urban economies and the dominant mestizo culture, and continue to practice traditional livelihood activities such as wild resource use and swidden agriculture in landscapes dominated by forest (Gray et al. 2008; Lu 2010). At the same time, all five groups have also taken advantage of new opportunities created by regional transformation, including to work for wages, sell agricultural products, accumulate manufactured goods, access government services, and engage in political activism (Lu 2007; Suarez et al. 2009; Bremner 2013). Increasing well-being has contributed to rapid population growth, with the indigenous population of Sucumbios and Orellana increasing from 40 thousand to 67 thousand between 2001 and 2010, 88% of whom continue to live in rural areas (INEC 2014).

*Household Surveys*

Our analysis draws on longitudinal household survey data collected in 2001 and 2012 in 32 indigenous communities of the NEA (Fig. 1). In 2001, a sample of communities was selected to include all five ethnicities and to span the regional spectrum of community accessibility and exposure to the outside world[1]. Within each community, 22 households were sampled for participation, either randomly or to include all households in smaller communities. In each sampled household, structured interviews were conducted with both the male and female heads of household in order to collect a wide variety of information on household characteristics and activities. Information about hunting, fishing, timber harvesting and forest product collection was gathered from the male head, or the female head if no male head was present, as described in detail below. 484 households completed a male interview and 476 completed both interviews. Community-level data was also collected through via structured interviews with community leaders and the use of GPS.

The 2012 follow-up survey targeted 489 households who successfully completed a female interview in 2001 and thus provided a household roster. Among these, 401 completed a male interview, 399 completed both interviews, and 75 had permanently left the area. Split-off households, where a 2001 household member was now male or female head, were also targeted. Among these, 200 completed a male interview, all of whom also completed a female interview. A questionnaire similar to the baseline was used, updated to include questions about changes experienced since 2001.

The male interview in both rounds collected detailed information about household participation in hunting, fishing, timber harvesting and forest product collection. For households that had hunted in the past year, the following information was collected about the most recent hunt: the duration of the hunt, the number of hunters, the equipment used, whether any game was sold, and the number, type and weight[2] of game caught. Additional questions were asked about normal hunting frequency and its changes over time, as well changes in resource quality over time. For households that had fished in the past year, a similar set of questions asked about the number of fishers, the equipment used, the number, type and weight of fish caught, sales of fish, and changes in fishing frequency and resource quality over time. Whether households collected or sold forest products was measured for several categories including firewood, fruit, medicinal plants, seeds, *barbasco*, *sangre de drago* (*Croton lechleri*), honey, plant fibers, mushrooms, timber and others. For households that sold timber in the past year, wood volume, income from sales and tree species (using local names) were collected for three levels of timber quality (high, medium and low), as well as reports of which timber species had become rare or extinct locally.

*Statistical Analyses*

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[1] Three communities from the baseline were excluded from the follow-up for logistical reasons, and in one community all baseline households had departed.
[2] Weights of game animals were collected only in 2012. We use mean weight per species in 2012 to estimate the weight of game in 2001.

We first use these data to describe various dimensions of wild resource use for the sample as a whole and by ethnicity (Table 1). Because most communities are ethnically mixed and many include non-indigenous (mestizo) residents, we classify households by the ethnicity of the male head. To compare values across time, we conduct Pearson's chi-squared tests for dichotomous variables and Wald tests for continuous variables, all of which are adjusted for clustering at the community level.

To better understand the drivers of these practices, we combine the data from 2001 and 2012 and use multilevel regression models (Skrondal & Rabe-Hesketh 2004) to predict nine key measures of resource use. Combining the two datasets creates a total sample of 1075 household-years with complete data[3]. To account for clustering at the household and community levels in this dataset, we estimate multilevel regression models with the following form:

$$y_{ijt} = y_{000} + \beta x_{ijt} + \delta w_{jt} + \alpha_j + u_{ij} + e_{ijt}$$

where $y_{ijt}$ is the outcome for household *i* in community *j* in year *t*, $y_{000}$ is an intercept, $\beta$ is a vector of household-level coefficients, $x_{ijt}$ is a vector of household-level predictors, $\delta$ is a vector of community-level coefficients, $w_{jt}$ is a vector of community-level predictors, $\alpha_j$ is the community-level random effect, $u_{ij}$ is the household-level random effect, and $e_{ijt}$ is the residual error term.

The nine outcomes that we examine using this approach include key measures of hunting, fishing, forest product collection and timber extraction. Hunting is measured by whether the household hunted in the past year (a dichotomous variable), and, for households that did, their reported frequency of hunting (a five point scale) and the weight of game harvested in the last outing (a continuous variable). Fishing is captured by whether the household fished in the past year (dichotomous), and for households that participated, the weight of fish harvested in the last fishing trip (continuous). Collection of non-timber forest products is measured by the number of types of products collected (continuous) and whether any products were sold (dichotomous). Finally, timber harvesting is captured by whether the household sold timber in the past year (dichotomous), and, if so, the volume sold (continuous). The multilevel model described above is estimated as a logit for dichotomous outcomes, as an ordered logit for hunting frequency, and as a linear model for continuous outcomes, which have been transformed as ln($x$+1) to remove skewness. Logit and ordered logit coefficients are presented as odds ratios, which can be interpreted as the multiplicative effect of a one unit increase in the predictor on the odds of participation, or, for ordered logit, the odds of being in a higher category.

The predictors included in these models are displayed in Table 2, and include measures of ethnicity, demographic characteristics, wealth[4], livelihood diversification, participation in conservation and development programs, and exposure to external markets and oil companies. This selection of predictors is consistent with the rural livelihoods framework (Ellis 2000) as well as with previous household-level studies of wild resource use (Amacher et al. 2009; Coomes et al. 2001; Godoy et al.

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[3] To account for the possibility of non-random selection into our cross-year sample, all analyses presented here were repeated using the subset of data from panel households who were interviewed twice, with results that are very similar to the results presented below.

[4] To construct a continuous measure of household wealth, we analyzed a common set of indictors for asset ownership and housing quality across the 2001 and 2012 datasets using polychoric principle components analysis, extracted the first principle component, and standardized this value to range from zero to ten (Kolenikov & Angeles 2009).

2010; Brashares et al. 2011). Examining changes in these measures over time (Table 2) reveals increases in household wealth, participation in conservation and development programs, levels of education, and accessibility to urban areas, as well as small changes in the ethnic composition of our sample due to the creation of new households and the departure or dissolution of old households.

## Results

Descriptive results are displayed in Table 1. The first panel reveals high participation in hunting with large declines across time, for the full sample and for all six ethnicities. The proportion of households who hunted in the past month, for example, declined from 72% to 47% ($p < 0.001$). Household effort per hunting trip also declined from 10.4 person-hours to 7.2 ($p = 0.020$). At the same time, the weight of animals harvested declined for birds only. Aggregating across all animals hunted, the global weight per animal increased from 7.8 to 9.4 kg, and the global weight hunted per person-hour increased from 1.4 to 1.7 kg. Households' own observations of changes in hunting similarly reveal decline in both the proportion of households reporting increased hunting as well those reporting declining resource quality. These changes occurred while hunting technology remained nearly the same (94-91% using firearms) and reported sales of game remained very rare (1-2% sold from the last hunt). Taken together, the results suggest declining participation in hunting that is not driven by declining resource quality.

Results in the second panel reveal similar results for fishing. Participation in fishing was high but declined across time for all ethnicities, from 84% of households in the past month to 67% for the full sample ($p < 0.001$). As for hunting, the weight per catch did not change significantly, the global weight per fish increased (0.73 to 0.98 kg), and the proportion of households reporting increases in participation or poorer resource quality both declined over time. The locally-named species composition of the catch also did not change noticeably over time, with *bagre* (*Siluriformes* spp.) remaining the most important fish by weight. Use of destructive fishing technologies such as dynamite and *barbasco* (*Lonchocarpus urucu*) was uncommon and became even rarer, as were market sales of fish.

The third and fourth panels describe harvesting of non-timber forest products and timber respectively. Similar to hunting and fishing, participation in non-timber harvesting was high but declined across time for all ethnicities, from 6.3 to 5.4 types of products collected per household for the full sample ($p < 0.001$). Participation in market sales also declined across time. However in contrast to the results for the three previous resource domains, the proportion of households harvesting any timber *increased* across time (from 67% to 79%; $p = 0.026$), the proportion selling timber declined only slightly (from 21% to 15%; $p = 0.18$), and the volume sold per participating household remained nearly constant (from 29 to 28 $m^3$; $p = 0.96$), though no Waorani households reported selling timber in either time period. Additionally, sales of high quality timber declined, and the high-quality species *cedro* (*Cedrela* sp.) went from the second-most harvested to rarely harvested. Many households also reported that *cedro* had become rare or extinct locally. Thus in contrast to the other three resource categories, the results for timber suggest flat participation and a declining resource base.

The results of our multilevel regression analyses (Table 3) provide additional insight into the drivers of these changes. All forms of resource use were significantly affected by ethnicity, demographic characteristics and the time trend, and some activities also responded to wealth, livelihood diversification, and exposure to factors such as external markets, oil companies or conservation and development programs. Participation in hunting was higher among younger, larger and more isolated households, and among the Secoya, Cofán and Waorani relative to the Kichwa. Among participating households, the reported frequency of hunting was lower among educated, wealthy and Shuar households, and higher among the Cofán and Waorani, whereas the weight harvested per hunt was lower among the Shuar and higher by wealthier households.

Participation in fishing was higher for younger and more isolated households and those exposed to conservation programs as well as oil companies (likely reflecting the placement of oil facilities along major rivers). Among fishing households, more fish were harvested per catch by households that were larger, wealthier and where the head was born locally. Participation in non-timber forest product collection (as measured by the number of types harvested), was higher among larger and older households and those that participated in conservation programs, and lower among Shuar and mestizo households. Participation in sales of forest products was higher among larger and less educated households, those that also participated in crop and labor markets, and among the Cofán and Waorani. Finally, participation in timber sales was higher among households closer to markets and those that sold crops, and lower among mestizo households and those that worked off-farm. The volume harvested was higher among the Shuar, Secoya and Cofán, and lower among households exposed to conservation programs.

Also notable is that the effect of the time trend (year 2012 relative to 2001) is negative is all nine models, including six in which the effect is highly significant and two in which it is marginally significant. This indicates that changes in the substantive predictors such as wealth and accessibility cannot account for the declining trends across time observed in Table 1. We speculate as to the origin of these effects below.

## Discussion

Our results provide important insights into the direction and drivers of social and environmental change in indigenous communities of the Amazon Basin. We observe that, with the partial exception of timber harvesting, participation in wild resource use is declining over time across multiple resource types and ethnic groups. This decline is occurring in the absence of strong evidence for degradation of the resource (with the exception of timber), during a period of increasing household wealth and well-being, and in the absence of landscape-scale environmental transformation (Holland et al. 2014). Use of multivariate approaches reveals that, consistent with the expectations of the rural livelihoods framework, ethnicity, demographic characteristics, wealth, livelihood diversification, participation in conservation programs, and exposure to external markets are all important predictors of resource use. However the opening presented for conservation interventions by these results is small at best:

Exposure to education, development programs, and conservation programs generally had mixed and weak effects on resource use.

Instead, our key finding for conservation practitioners is that declines in wild resource use largely *cannot* be accounted for by changing household and community characteristics, and that region-wide processes of change are the likely drivers. Like many formerly remote Latin American forest frontiers, over recent decades the NEA has experienced rapid urbanization, agricultural colonization, and expansion of government infrastructure and services (Browder 1997). Across all five indigenous groups, these changes have increased exposure to new sources of income, new expectations of material prosperity, and new services such as education and development programs (Lu 2007; Suarez et al. 2009; Bremner 2013), above and beyond what we are able to account for in our regression analysis, and we hypothesize that these region-wide processes of modernization are the key drivers of declining resource use. If that is the case, similar dynamics may be at work on many other forest frontiers that are increasingly influenced by external economies, societies and governance. Regardless, these changes do not remove potential threats to biodiversity posed by these practices, given that the number of households in these communities is also growing rapidly.

For conservation scientists, our work also illustrates the utility of methods from the quantitative social sciences for understanding small-scale resource use (see also Amacher et al. 2009; Coomes et al. 2001; Godoy et al. 2010; Brashares et al. 2011). Through the use of repeated household surveys, we are able to provide region-wide quantitative estimates of resource use practices that are rarely observed at this scale. Desirable extensions of this approach include integration with biological sampling, extension to a larger sample of communities, and replication in other study areas.

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**Table 1. Wild product harvesting by ethnicity.**

| Measure of harvest | Full sample | | | Kichwa | | | Shuar | | | Secoya | | | Cofan | | | Waorani | | | Mestizo | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2012 | | 2001 | 2012 | | 2001 | 2012 | | 2001 | 2012 | | 2001 | 2012 | | 2001 | 2012 | | 2001 | 2012 | |
| **Hunting** | | | | | | | | | | | | | | | | | | | | | |
| Hunted in past month (0/1) | 0.72 | 0.47 | *** | 0.69 | 0.42 | *** | 0.62 | 0.45 | + | 0.82 | 0.50 | ** | 0.80 | 0.72 | | 0.88 | 0.65 | + | 0.67 | 0.44 | * |
| Hunted in past year (0/1) | 0.88 | 0.65 | *** | 0.84 | 0.59 | *** | 0.84 | 0.64 | ** | 1.00 | 0.76 | | 0.93 | 0.87 | | 0.98 | 0.87 | * | 0.83 | 0.59 | |
| Animals hunted (#) | 1.84 | 1.28 | ** | 1.62 | 1.15 | * | 1.36 | 0.89 | * | 2.53 | 1.34 | | 1.85 | 2.05 | | 2.83 | 1.74 | | 1.40 | 1.00 | |
| Weight of animals (kg) | 14.4 | 12.1 | | 12.8 | 9.7 | | 8.5 | 9.2 | | 27.2 | 12.0 | | 15.8 | 15.1 | | 19.4 | 26.7 | | 12.5 | 5.6 | |
| Weight of peccaries (kg) | 6.6 | 7.0 | | 5.8 | 5.6 | | 2.3 | 5.7 | | 8.3 | 5.8 | | 8.5 | 6.2 | | 11.4 | 17.2 | | 8.7 | 3.7 | |
| Weight of rodents (kg) | 2.4 | 2.2 | | 2.4 | 2.0 | | 2.6 | 2.9 | | 3.5 | 3.5 | | 4.2 | 3.4 | | 0.6 | 1.5 | | 2.7 | 0.8 | * |
| Weight of monkeys (kg) | 1.3 | 1.0 | | 1.5 | 0.5 | + | 1.3 | 0.1 | | 1.2 | 0.9 | | 0.6 | 3.3 | | 1.2 | 2.5 | | 0.0 | 0.2 | |
| Weight of birds (lbs) | 1.0 | 0.3 | ** | 0.8 | 0.3 | *** | 0.7 | 0.3 | | 0.5 | 0.2 | + | 0.4 | 0.4 | | 3.0 | 0.7 | | 0.6 | 0.1 | + |
| Weight of others (lbs) | 3.2 | 1.7 | | 2.4 | 1.3 | | 1.5 | 0.2 | | 13.5 | 1.7 | ** | 2.1 | 1.8 | | 3.2 | 4.9 | | 0.6 | 0.7 | |
| Person-hours hunting (hrs) | 10.4 | 7.2 | * | 9.6 | 7.0 | + | 13.1 | 5.4 | + | 9.2 | 8.9 | | 8.9 | 10.9 | | 10.8 | 6.8 | | 10.9 | 6.2 | |
| Used a firearm (0/1) | 0.94 | 0.91 | + | 0.98 | 0.96 | | 0.91 | 0.85 | | 0.94 | 0.97 | | 0.95 | 0.93 | | 0.83 | 0.72 | | 1.00 | 0.88 | |
| Sold meat (0/1) | 0.02 | 0.01 | | 0.02 | 0.02 | | 0.03 | 0.00 | | 0.00 | 0.03 | | 0.00 | 0.00 | | 0.02 | 0.00 | | 0.07 | 0.00 | |
| Hunting frequency (0-4) | 2.29 | 1.73 | *** | 2.25 | 1.66 | *** | 1.76 | 1.36 | * | 2.15 | 1.21 | | 2.76 | 2.33 | | 2.76 | 2.34 | | 2.47 | 1.54 | * |
| Hunt more than in past (0/1) | 0.14 | 0.04 | *** | 0.14 | 0.04 | *** | 0.12 | 0.02 | * | 0.21 | 0.06 | | 0.17 | 0.09 | | 0.12 | 0.04 | | 0.22 | 0.00 | + |
| Hunt less than in past (0/1) | 0.73 | 0.79 | | 0.75 | 0.83 | | 0.79 | 0.94 | + | 0.79 | 0.88 | | 0.83 | 0.67 | + | 0.51 | 0.43 | | 0.56 | 0.90 | * |
| Hunting is better (0/1) | 0.05 | 0.09 | | 0.05 | 0.06 | | 0.10 | 0.13 | | 0.00 | 0.10 | ** | 0.05 | 0.23 | | 0.02 | 0.04 | | 0.11 | 0.13 | |
| Hunting is worse (0/1) | 0.86 | 0.69 | *** | 0.91 | 0.79 | ** | 0.79 | 0.71 | | 0.86 | 0.69 | | 0.93 | 0.63 | | 0.65 | 0.28 | + | 0.78 | 0.67 | |
| **Fishing** | | | | | | | | | | | | | | | | | | | | | |
| Fished in past month (0/1) | 0.84 | 0.67 | *** | 0.85 | 0.67 | *** | 0.75 | 0.60 | + | 0.85 | 0.74 | | 0.86 | 0.72 | + | 0.97 | 0.74 | | 0.61 | 0.51 | |
| Fished in past year (0/1) | 0.95 | 0.84 | *** | 0.94 | 0.84 | *** | 0.96 | 0.77 | ** | 1.00 | 0.92 | | 0.95 | 0.91 | * | 1.00 | 0.91 | | 0.83 | 0.68 | |
| Fish caught (#) | 19.3 | 12.8 | ** | 15.6 | 12.3 | | 31.1 | 12.9 | * | 16.9 | 11.2 | | 14.9 | 14.1 | | 20.7 | 15.0 | | 17.2 | 14.0 | |
| Weight of fish (kg) | 6.4 | 5.7 | | 6.2 | 4.8 | * | 3.7 | 2.6 | | 4.8 | 6.7 | | 10.1 | 12.4 | | 9.6 | 8.2 | | 3.0 | 5.3 | |
| Used *barbasco* (0/1) | 0.09 | 0.04 | *** | 0.05 | 0.02 | | 0.27 | 0.11 | ** | 0.00 | 0.00 | | 0.00 | 0.00 | | 0.09 | 0.12 | | 0.13 | 0.04 | |
| Used dynamite (0/1) | 0.04 | 0.01 | ** | 0.03 | 0.00 | * | 0.06 | 0.00 | | 0.00 | 0.00 | | 0.02 | 0.02 | | 0.06 | 0.00 | | 0.20 | 0.04 | ** |
| Sold fish (0/1) | 0.02 | 0.00 | * | 0.02 | 0.00 | * | 0.00 | 0.00 | | 0.03 | 0.03 | | 0.05 | 0.02 | | 0.00 | 0.00 | | 0.00 | 0.00 | |
| Fish more now (0/1) | 0.15 | 0.06 | * | 0.17 | 0.07 | | 0.12 | 0.03 | | 0.13 | 0.06 | | 0.14 | 0.05 | | 0.18 | 0.04 | * | 0.11 | 0.00 | |
| Fish less now (0/1) | 0.63 | 0.69 | | 0.66 | 0.66 | | 0.68 | 0.91 | * | 0.61 | 0.78 | | 0.74 | 0.67 | | 0.34 | 0.37 | | 0.56 | 0.85 | |
| Fishing is better (0/1) | 0.05 | 0.06 | | 0.04 | 0.07 | | 0.05 | 0.03 | | 0.10 | 0.00 | | 0.05 | 0.12 | | 0.05 | 0.10 | | 0.00 | 0.00 | |
| Fishing is worse (0/1) | 0.73 | 0.56 | *** | 0.78 | 0.58 | ** | 0.78 | 0.70 | | 0.65 | 0.58 | | 0.79 | 0.53 | | 0.48 | 0.18 | * | 0.56 | 0.72 | |
| **Non-timber forest products** | | | | | | | | | | | | | | | | | | | | | |
| Types collected (#) | 6.30 | 5.37 | *** | 6.56 | 5.41 | *** | 5.06 | 4.85 | | 5.47 | 4.87 | | 6.30 | 5.46 | ** | 7.77 | 7.48 | | 5.33 | 3.66 | + |
| Collect firewood (0/1) | 0.92 | 0.93 | | 0.94 | 0.96 | | 0.80 | 0.91 | + | 0.97 | 0.97 | | 0.95 | 0.93 | | 1.00 | 0.98 | | 0.89 | 0.68 | |
| Collect fruit (0/1) | 0.85 | 0.83 | | 0.87 | 0.83 | | 0.66 | 0.72 | | 0.94 | 0.95 | | 0.91 | 0.85 | | 0.97 | 1.00 | | 0.61 | 0.66 | |
| Collect medicine (0/1) | 0.81 | 0.71 | * | 0.87 | 0.68 | *** | 0.52 | 0.64 | | 0.85 | 0.76 | | 0.98 | 0.98 | | 0.92 | 0.91 | | 0.61 | 0.51 | |
| Collect seeds (0/1) | 0.56 | 0.48 | + | 0.57 | 0.42 | ** | 0.33 | 0.47 | + | 0.47 | 0.47 | | 0.73 | 0.63 | | 0.83 | 0.87 | | 0.44 | 0.29 | |
| Collect *barbasco* (0/1) | 0.60 | 0.57 | | 0.57 | 0.54 | | 0.49 | 0.56 | | 0.50 | 0.47 | | 0.57 | 0.70 | | 0.92 | 0.87 | * | 0.50 | 0.44 | |
| Collect *sangre de drago* (0/1) | 0.61 | 0.50 | ** | 0.64 | 0.50 | * | 0.48 | 0.48 | | 0.56 | 0.55 | | 0.48 | 0.39 | | 0.83 | 0.69 | | 0.56 | 0.34 | + |
| Collect honey (0/1) | 0.56 | 0.39 | *** | 0.57 | 0.40 | * | 0.44 | 0.34 | | 0.29 | 0.21 | | 0.48 | 0.30 | | 0.95 | 0.78 | * | 0.39 | 0.27 | |
| Collect plant fibers (0/1) | 0.81 | 0.60 | *** | 0.82 | 0.63 | ** | 0.62 | 0.48 | | 0.79 | 0.42 | | 0.98 | 0.59 | ** | 0.95 | 0.96 | | 0.67 | 0.37 | * |
| Collect mushrooms (0/1) | 0.46 | 0.35 | * | 0.61 | 0.46 | ** | 0.44 | 0.26 | * | 0.09 | 0.05 | | 0.18 | 0.09 | | 0.30 | 0.43 | | 0.44 | 0.10 | * |
| Collect other (0/1) | 0.12 | 0.01 | *** | 0.10 | 0.01 | *** | 0.28 | 0.01 | ** | 0.00 | 0.00 | | 0.05 | 0.00 | | 0.09 | 0.00 | | 0.22 | 0.00 | * |
| Sold forest product (0/1) | 0.22 | 0.12 | ** | 0.11 | 0.08 | | 0.17 | 0.09 | | 0.09 | 0.21 | | 0.73 | 0.30 | | 0.48 | 0.28 | | 0.06 | 0.05 | |
| **Timber** | | | | | | | | | | | | | | | | | | | | | |
| Harvest timber (0/1) | 0.67 | 0.79 | * | 0.73 | 0.83 | | 0.51 | 0.74 | * | 0.76 | 0.63 | | 0.66 | 0.78 | | 0.66 | 0.91 | * | 0.50 | 0.56 | |
| Sold any timber (0/1) | 0.21 | 0.15 | | 0.23 | 0.17 | | 0.36 | 0.22 | | 0.38 | 0.18 | | 0.09 | 0.17 | + | 0.00 | 0.00 | | 0.11 | 0.00 | + |
| Volume sold ($m^3$) | 28.7 | 28.0 | | 12.9 | 10.4 | | 27.2 | 80.7 | * | 113 | 28.2 | | 11.4 | 24.9 | | - | - | | 1.4 | - | |
| Sold high qual. timber (0/1) | 0.13 | 0.05 | ** | 0.13 | 0.03 | *** | 0.25 | 0.10 | * | 0.18 | 0.18 | | 0.05 | 0.11 | * | 0.00 | 0.00 | | 0.11 | 0.00 | + |
| Sold medium qual. timber (0/1) | 0.13 | 0.12 | | 0.14 | 0.15 | | 0.19 | 0.14 | | 0.21 | 0.08 | | 0.09 | 0.11 | | 0.00 | 0.00 | | 0.00 | 0.00 | |
| Sold low qual. timber (0/1) | 0.03 | 0.01 | + | 0.06 | 0.02 | * | 0.02 | 0.00 | | 0.03 | 0.00 | | 0.00 | 0.02 | | 0.00 | 0.00 | | 0.00 | 0.00 | |
| Sample housholds | 484 | 601 | | 235 | 336 | | 89 | 86 | | 34 | 38 | | 44 | 46 | | 64 | 54 | | 18 | 41 | |
| Sample communities | 32 | 32 | | 14 | 14 | | 8 | 8 | | 2 | 2 | | 3 | 3 | | 5 | 5 | | 0 | 0 | |
| Total HH in communities | 897 | 1242 | | 522 | 738 | | 100 | 169 | | 90 | 95 | | 109 | 114 | | 76 | 126 | | - | - | |
| Total pop. in communties | 4930 | 7363 | | 2776 | 4332 | | 619 | 950 | | 326 | 530 | | 679 | 779 | | 530 | 772 | | - | - | |

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

**Table 2. Definitions and mean values for the independent variables.**

| Predictor | Mean values 2001 | Mean values 2012 | Definition |
|---|---|---|---|
| Characteristics of the head | | | |
| Kichwa (0/1) | 0.49 | 0.56 | Ethnicity of head is Kichwa; reference category |
| Shuar (0/1) | 0.18 | 0.14 | Ethnicity of head is Shuar |
| Secoya (0/1) | 0.07 | 0.06 | Ethnicity of head is Secoya |
| Cofan (0/1) | 0.09 | 0.08 | Ethnicity of head is Cofan |
| Waorani (0/1) | 0.13 | 0.09 | Ethnicity of head is Huaorani |
| Mestizo (0/1) | 0.04 | 0.07 | Ethnicity of head is Mestizo |
| Age (years) | 39.0 | 41.0 | Age of head |
| Born in community (0/1) | 0.28 | 0.38 | Head was born in the community |
| Primary education (0/1) | 0.58 | 0.75 | Head has completed primary education |
| Household characteristics | | | |
| Household size (#) | 6.34 | 6.19 | Individuals resident in household |
| Wealth index (0-10) | 2.83 | 4.81 | Continous wealth index ranging from 0-10; see text |
| Sold crops (0/1) | 0.68 | 0.68 | Household sold crops in the past year |
| Owns cattle (0/1) | 0.15 | 0.16 | Household owns cattle |
| Off-farm employment (0/1) | 0.58 | 0.52 | Member worked off-farm in past year |
| Cash transfer (0/1) | 0.00 | 0.44 | Household recieves *bono de desarrollo humano* [1] |
| $N_{households}$ | 476 | 599 | |
| Community characteristics | | | |
| Travel time (hours) | 3.51 | 2.44 | Total travel time to closest urban area |
| Oil company (0/1) | 0.47 | 0.41 | Oil company employs two or more community members |
| Conservation program (0/1) | 0.38 | 0.66 | Conservation programs active in past 10 years |
| $N_{communities}$ | 32 | 32 | |

[1] Lacking detailed data on participation in a small-scale precursor program before 2003, we treat all households as non-participants in 2001.

**Table 3. Results of the regression analysis of wild product harvesting (coefficients and significance tests).**

| Predictor | Hunting | | | Fishing | | Non-timber forest products | | Timber | |
|---|---|---|---|---|---|---|---|---|---|
| | Hunted in past year | Hunting frequency | Ln(weight harvested+1) | Fished in past year | Ln(weight harvested+1) | Types harvested | Sold product | Sold timber | Ln(volume sold+1) |
| Characteristics of the head | | | | | | | | | |
| Shuar | 1.44 | 0.54 * | -0.53 * | 0.95 | -0.19 | -1.21 ** | 1.44 | 1.20 | 0.52 * |
| Secoya | 4.32 * | 0.78 | 0.45 | 3.50 | 0.27 | -0.30 | 2.36 + | 1.39 | 0.68 * |
| Cofan | 4.63 ** | 2.47 ** | 0.26 | 1.42 | 0.17 | -0.16 | 7.94 *** | 0.84 | 0.96 * |
| Waorani | 7.29 *** | 2.31 ** | 0.52 + | 1.41 | 0.23 | 0.03 | 5.94 *** | - | - |
| Mestizo | 1.29 | 1.08 | -0.33 | 0.39 + | -0.17 | -1.16 *** | 0.59 | 0.16 * | -1.30 + |
| Age | 0.97 *** | 1.00 | 0.00 | 0.96 *** | 0.00 | 0.01 ** | 1.01 | 0.98 + | 0.01 |
| Born in community | 1.02 | 1.18 | 0.12 | 1.76 | 0.23 ** | 0.29 + | 0.80 | 0.87 | -0.34 |
| Primary education | 0.88 | 0.69 * | -0.01 | 0.68 | 0.09 | 0.16 | 0.56 * | 1.06 | 0.34 + |
| Household characteristics | | | | | | | | | |
| Household size | 1.15 *** | 1.01 | 0.00 | 1.03 | 0.03 * | 0.09 *** | 1.08 * | 1.03 | 0.04 |
| Wealth index | 0.92 | 0.91 * | 0.07 * | 1.03 | 0.06 ** | -0.06 | 0.90 | 1.00 | 0.09 + |
| Sold crops | 1.31 | 0.98 | 0.03 | 1.73 + | -0.09 | 0.21 | 1.66 * | 2.23 ** | 0.08 |
| Owns cattle | 1.05 | 0.79 | -0.10 | 1.19 | 0.08 | 0.15 | 0.98 | 1.62 + | -0.18 |
| Off-farm employment | 0.76 | 1.18 | -0.01 | 0.94 | 0.02 | 0.21 | 1.61 * | 0.49 *** | -0.12 |
| Cash transfer | 1.21 | 1.41 + | 0.01 | 1.12 | -0.06 | 0.07 | 0.94 | 1.06 | 0.05 |
| Community characteristics | | | | | | | | | |
| Travel time | 1.21 *** | 1.03 | 0.01 | 1.34 ** | -0.02 | 0.00 | 1.03 | 0.70 ** | -0.01 |
| Oil company | 0.94 | 0.95 | 0.20 | 2.77 ** | -0.12 | -0.13 | 0.79 | 1.19 | -0.13 |
| Conservation program | 1.15 | 0.95 | -0.05 | 2.72 ** | 0.16 + | 0.43 ** | 1.46 | 0.60 + | -0.44 * |
| Year is 2012 | 0.24 *** | 0.36 *** | -0.38 ** | 0.22 *** | -0.17 + | -0.94 *** | 0.63 + | 0.44 ** | -0.16 |
| Model | Logit | Ordered logit | OLS | Logit | OLS | OLS | Logit | Logit | OLS |
| Interpretation | Odds ratios[1] | Odds ratios | Coefficients | Odds ratios | Coefficients | Coefficients | Odds ratios | Odds ratios | Coefficients |
| $N_{households}$ | 1075 | 810 | 810 | 1075 | 879 | 1075 | 1075 | 958 | 176 |

[1] Odds ratios can interpreted as a multiplicative effect on the odds of participation. Thus, values less than 1 represent a negative effect.

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Figure 1. Map of the study area.