



Original Article

Evidence of traditional knowledge loss among a contemporary indigenous society

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ABSTRACT

As biological and linguistic diversity, the world's cultural diversity is on decline. However, to date there are no estimates of the rate at which the specific cultural traits of a group disappear, mainly because we lack empirical data to assess how the cultural traits of a given population change over time. Here we estimate changes in cultural traits associated to the traditional knowledge of wild plant uses among an Amazonian indigenous society. We collected data among 1151 Tsimane' Amerindians at two periods of time. Results show that between 2000 and 2009, Tsimane' adults experienced a net decrease in the report of plant uses ranging from 9% (for the female subsample) to 26% (for the subsample of people living close to towns), equivalent to 1% to 3% per year. Results from a Monte Carlo simulation show that the observed changes were not the result of randomness. Changes were more acute for men than for women and for informants living in villages close to market towns than for informants settled in remote villages. The Tsimane' could be abandoning their traditional knowledge as they perceive that this form of knowledge does not equip them well to deal with the new socio-economic and cultural conditions they face nowadays.

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1. Introduction

Researchers agree that many drivers are potentially responsible for cultural change and that the rate at which such cultural traits change varies across cultures and time periods (Boyd & Richerson, 2005). Working under the framework of cultural evolutionary theory, several authors have attempted to explain the mechanisms and processes that drive cultural change. Such work has identified a set of factors that, working alone or in combination, provide plausible explanations for rates of cultural change at different points of time (Mace, Holden, & Shennan, 2005; Mesoudi, *in press*). For example, Rogers and Ehrlich's (2008) finding that functional features of Polynesian canoes change less rapidly than stylistic non-functional traits suggests that intrinsic characteristics of a given technology might affect rates of technological change. Differently, Henrich's modelling work (Henrich, 2004) suggests that a reduction in population size was the main factor driving the technological loss in Tasmania. Other factors affecting rates of cultural change include external environmental change

(Richerson, Boyd, & Bettinger, 2001), technology manufacturing costs (Martin, 2000), fit between new and previous knowledge (Rogers, 1995), external representation of knowledge (Leonti, 2011), social network structure and social institutions (Tehrani & Collard, 2009, Henrich & Henrich, 2010), or inter-group conflict (Di Cosmo, 2002). Furthermore, random copying and cultural drift can also drive changes in cultural traits (Bentley, Hahn, & Shennan, 2004).

Besides providing explanations for the drivers of cultural change, researchers have also attempted to calculate the rate at which different cultural traits change. Generalizations from this body of research have proven challenging for two main reasons. First, when assessing cultural change, researchers have used different temporal scales and different units of analysis derived from different human behavior, and including material culture, social organization and language (Aunger, 2000a, Mace et al., 2005). Although the scale and unit of analysis are probably related to the nature of the research (e.g., archaeologists are typically constrained to artifacts, whilst anthropologists focus on the measure knowledge and/or behavior), diversity in units of analysis hampers the comparability of research results. Second, the study of cultural change requires a diachronic perspective that is not necessarily implicit in all the disciplines addressing the study of cultural change (such as anthropology). While modelling frameworks (Boyd & Richerson, 2005), including models of

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macroevolutionary change and cumulative cultural evolution (Aoki, Lehmann, & Feldman, 2011; Enquist, Ghirlanda, & Eriksson, 2011), and phylogenetic methods (Mace et al., 2005) stress the diachronic perspective, anthropologists attempting to assess cultural change in contemporary societies have often been less well-equipped. For example, previous anthropological research on the secular changes on traditional knowledge has relied on cross-sectional data comparing measures 1) among people of different ages and cohorts (Benz, Cevallos, Santana, Rosales, & Graf, 2000; Demps, Zorondo-Rodriguez, García, & Reyes-García, 2012; Godoy et al., 2009a; Gomez-Baggethun, Mingorria, Reyes-García, Calvet, & Montes, 2010), or 2) among people living at different levels of cultural and economic isolation (Reyes-García et al., 2005). But anthropologists typically lack diachronic data for the study of cultural change.

Here we contribute to research on rates and factors affecting cultural change in contemporary indigenous societies by using a different methodological approach. We use contemporary data collected over two periods of time to assess changes in traditional knowledge among a highly autarkic foraging–farming society of native Amazonians. We focus on traditional knowledge, *sensu* Berkes (Berkes, Colding, & Folke, 2000), because this form of knowledge seems to be declining in many parts of the world (Benz et al., 2000; Maffi, 2002; Perales, Benz, & Brush, 2005; Gomez-Baggethun et al., 2010). We address two main research questions. First, to what extent does contemporary traditional knowledge change over short periods of time? And second, what factors are likely to explain changes in traditional knowledge? In answering both questions we provide the first empirical estimate of the rate at which traditional knowledge changes in a contemporaneous indigenous society, and the factors associated to such change.

2. Methods

2.1. Study population

The Tsimane' are the third largest ethnic group in the Bolivian lowlands with about 10,000 people living in about 125 villages, mostly in the province of Beni. The Tsimane' live in small communities of about 20 households, along riverbanks and logging roads. The Tsimane' economy is primarily based on hunting, fishing, and slash-and-burn farming, with cash cropping of rice becoming a dominant form of monetary income (Vadez et al., 2008). The Tsimane' also sell and barter agricultural, timber and non-timber forest products in nearby towns or to traveling traders who visit their villages.

2.2. Subject recruitment, study design, and sample

The *Gran Consejo Tsimane'* (the Tsimane' political organization) approved the study protocol and prior informed consent was obtained from each participant. Refusal to participate was low (<5%). We collected information twice: once during 2000 and once during 2008–2009 (hereafter 2009). In 2000 we selected 58 villages based on a census carried out by the *Gran Consejo Tsimane'* (Reyes-García et al., 2003) and in 2009 we selected 66 villages using a census from our previous work in the area (Reyes-García et al., 2012). In both years we selected villages with different levels of distance from a main road or market town (Fig. 1). In communities with 10 or less households we surveyed all the households; in communities with 11 to 40 households we randomly selected 10 households from a list provided by the highest-ranking authority, and in communities larger than 40 households we randomly selected 25% of the households. To adhere to cultural norms, within a household we interviewed the male household head ($n = 867$) and the female ($n = 304$) when the male was not available. During our 2009 visit to villages previously visited in 2000, we also sought the informants interviewed in 2000, though we were able to locate only a fraction of them. As several

authors have suggested that the accumulation of traditional knowledge likely peaks in the late teens (e.g., Zarger, 2002), we restricted our analysis to people aged 20 years or older. Our final sample consists of 1151 individuals: 473 Tsimane' adults from 58 villages interviewed in 2000 and 678 Tsimane' adults from 66 villages interviewed in 2009. Forty-two villages were visited twice and 135 people were interviewed in both surveys.

2.3. Measure of traditional knowledge

We estimated an individual's traditional knowledge using a test designed to quantify individual knowledge of wild plants uses. We used previous work in the area (Reyes-García, Huanca, Vadez, Leonard, & Wilkie, 2006) to identify cultural domains that correspond to emic semantic constructs that bear psychological reality for the Tsimane'. The specific cognitive domains identified correspond to five types of plant uses that seemed to be culturally valid: plants that can be used as medicine, food, firewood, canoe and house building.

We used responses to a free-listing exercise ($n = 50$) on Tsimane' useful plants to randomly select 20 plants for further evaluation. We constructed a multiple choice questionnaire with 20 plants and 5 plant uses to capture informant's knowledge of 100 plant use reports. All survey respondents were asked to report on whether each plant could be used for each of the identified domains of plant uses. Multiple uses per plant were recorded (Reyes-García et al., 2005). Our measure of traditional knowledge consists of the sum of all possible distinctive uses (i.e., several medicinal uses of a plant are only counted as one – medicinal) of the plants in our questionnaire across the five categories of use. The same exact test was used in years 2000 and 2009.

2.4. Demographic survey

To capture individuals' characteristics that might affect levels of traditional knowledge we conducted a demographic survey amongst all study participants. Participants were asked to estimate their age in years. As many adults did not know their exact age they guessed, thereby introducing a random measurement error in the age variable. We used the survey year and the participants' self-reported age to create dummy variables for seven cohorts or birth decades (1920s to 1980s, both inclusive). Because several authors have argued that education affects the acquisition of traditional knowledge (Sternberg et al., 2001), we also included a control for the maximum education level of the person. Informant's ability to communicate in Spanish (the language spoken by non-Tsimane' in the area and a proxy for acculturation) was assessed at the time of the interview and included in our model as a dummy variable that took the value of 1 if the person could communicate fluently in Spanish and 0 otherwise.

The measure of traditional knowledge and the survey were developed after extensive ethnographic observation. In 1999–2000, prior to the first round of data collection, the instruments were tested during an 18-month stay in two communities with different levels of market integration. To ensure uniformity, the lead author trained interviewers in both survey rounds. We entered data into a database and conducted standard data cleaning procedures.

2.5. Data analysis

To analyze changes across decades of birth and survey years, for each cohort we run a t-test comparing data collected in 2000 and 2009. We tested whether observed changes were the result of randomness (i.e., copying or cultural drift processes (Boyd & Richerson, 1985; Hahn & Bentley, 2003; Herzog, Bentley, & Hahn, 2004) by running Monte Carlo simulations with two indices: the mean number of plant uses known per individual and the diversity of plant uses, as defined by Neiman (1995) and Pérez-Losada and Fort (2011). While the measure of plant uses reported portrays changes

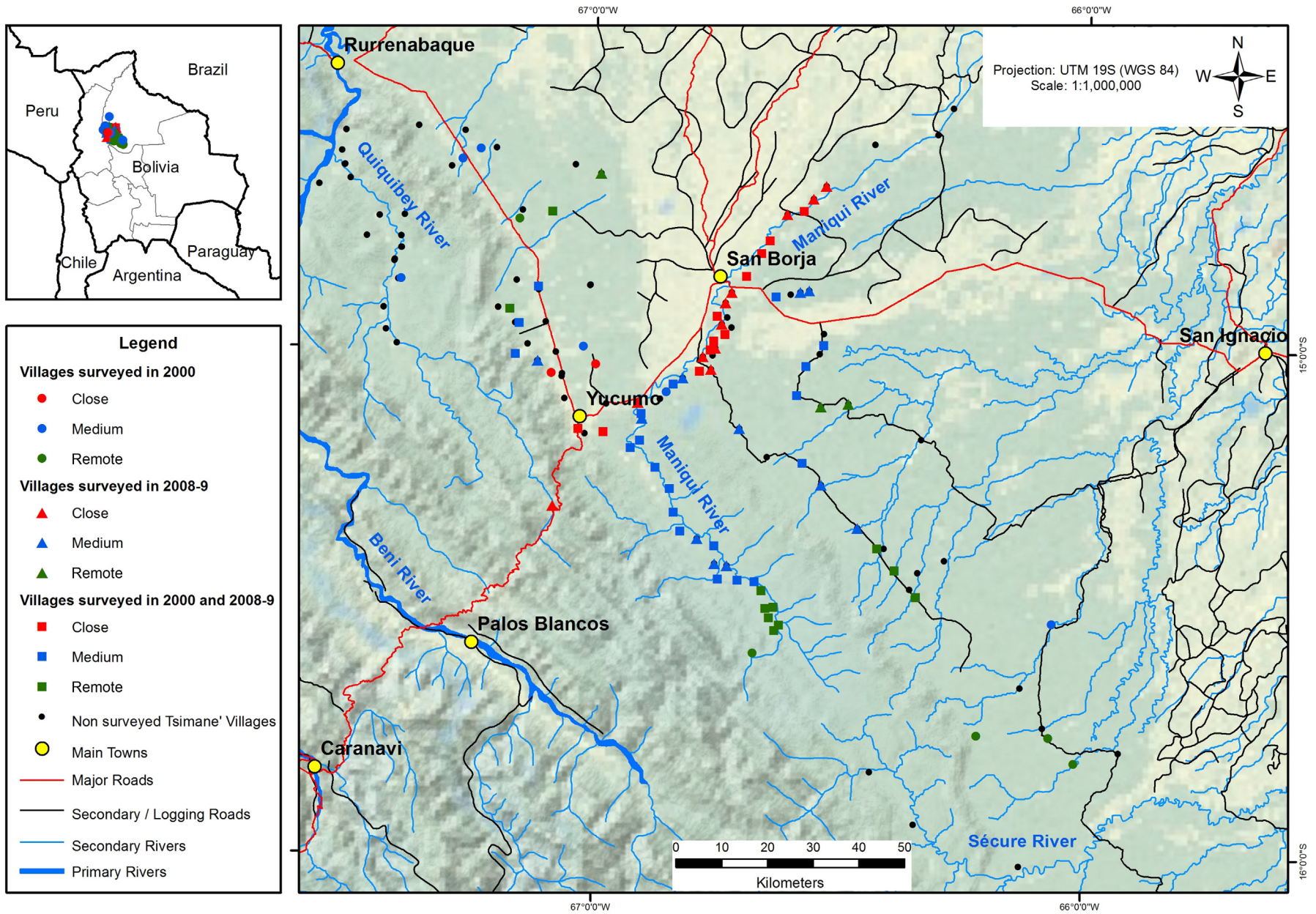


Fig. 1. Map of study area with Tsimane' villages categorized by year of the survey (non-surveyed, 2000, 2008–2009, or both) and by remoteness (close, medium, and remote).

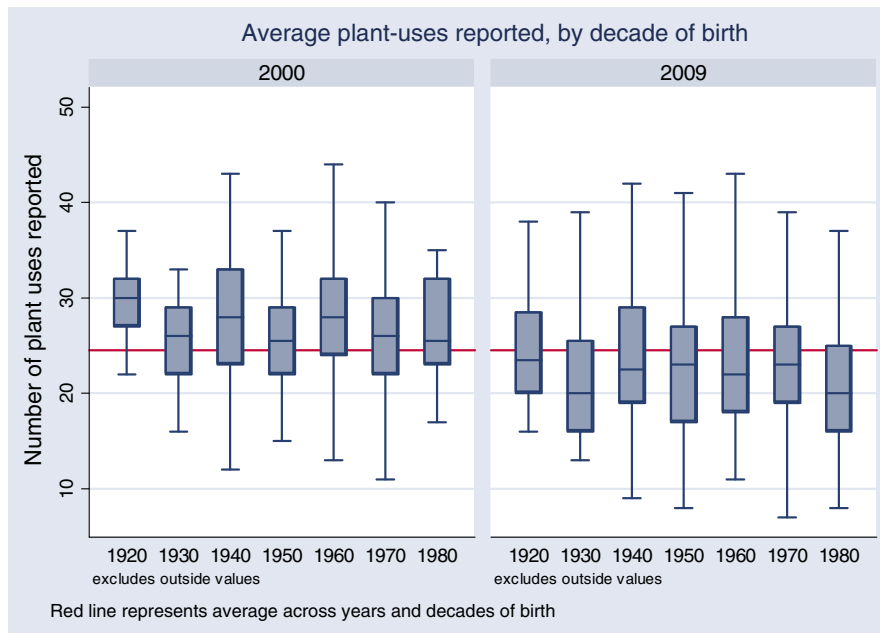


Fig. 2. Average number of plant uses reported by Tsimane' adults (> 20 years of age, n = 1151), by birth cohort and survey year.

across individuals, it does not reflect to what extent the knowledge is shared. Two samples may have the same mean but substantially differ as regards the number of specialized individuals and hence the diversity of knowledge.

To compute Monte Carlo simulations we first created a population about 20 times bigger than the initial population sampled in 2000 (on the assumption that about 5% of the total population was surveyed). Random changes were executed in the plant uses reports of every individual, with a probability defined at the beginning of the simulation. We calculated the diversity and mean plant uses reported per individual from a 5% of the virtual population and compared the results with data from the 2009 survey. As the probability of random cultural change was unknown, we repeated the process 10,000 times for 20 randomness values from 0% to 100% with lags of 0.05 (0.05, 0.10, ...).

We also tested whether the observed changes were associated to informants' proximity to market towns, a proxy for changes in economic, social, and environmental conditions. To do so, we first created an index of remoteness by adapting the formula proposed by Eisenberg et al. (2006). For each village we calculated the linear distance to the nearest market town using GPS readings collected at the village center. We also recorded the monetary cost of traveling to the nearest market town. We used those two values to calculate a rank of remoteness (R_i) for each village i , by averaging normalized values of distance (D_i) and cost (C_i). Specifically,

$$R_i = (D_i / Avg D_{1-n}) + (C_i / Avg C_{1-n})$$

where values close to 0 indicate proximity to a market town. In statistical analysis we used our index of remoteness in two different

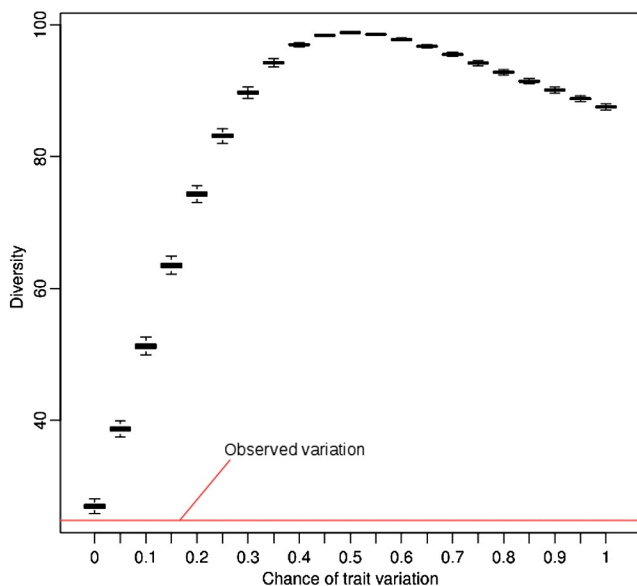


Fig. 3. Boxplot depicting the variation of diversity on Monte Carlo simulations in relation to real observed variation. The figure shows the diversity distribution for each tested variation probability (from 0 to 1), as well as the 2009 observed variation (red line).

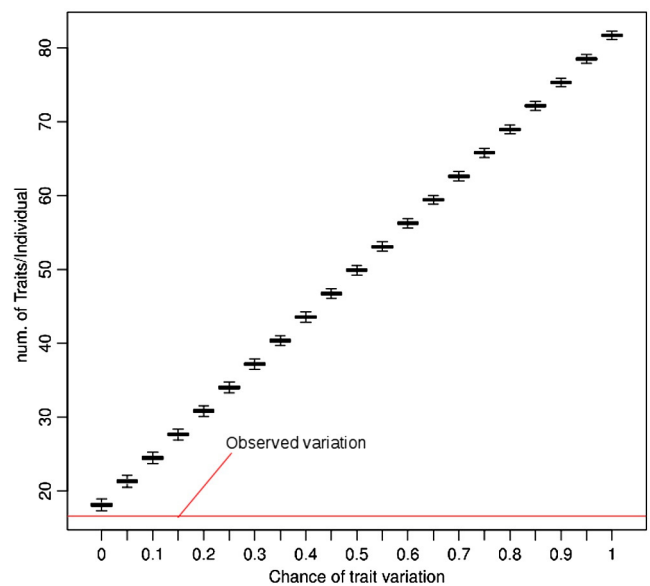


Fig. 4. Boxplot depicting the variation of number of traits known per individual on Monte Carlo simulations in relation to real observed variation. The figure shows the number of traits/individual distribution for each tested variation probability (from 0 to 1), as well as the 2009 observed variation (red line).

Table 1

Sample size, distance to the closes market town, and average number of plant uses reported, by year of survey and remoteness.

Remoteness category	Villages (n)		Participants (n)		Average distance to closest market town (km)		Average plant uses reported (%)	
	2000	2009	2000	2009	2000	2009	2000	2009
Close	16	25	149	270	12.52	14.23	26.44	19.77
Medium	19	22	157	250	32.23	31.07	27.13	22.80
Remote	23	19	167	158	58.78	53.39	27.98	23.69
Overall	58	66	473	678	37.32	31.12	27.28	21.91

ways, as a continuous variable and as a categorical variable with three values (“close”, “medium”, and “remote”), each including 33% of the villages in the sample.

To estimate changes in the number of plant uses reported by informants over the two survey years, we used a multivariate Ordinary Least Square regression model with the logarithm of the *number of plant uses reported* as the outcome variable and a dummy variable that took the value of 1 if the survey was conducted in the year 2009 as the main explanatory variable. As the outcome variable is in logarithms, the coefficient of the variable *year 2009* can be read as the percentage change in plant use occurring during the two survey years (2000 and 2009). We use the coefficient of the variable *year 2009* to estimate the annual rate of change. Regressions included individual-level controls for a) the sex of the person answering to the survey, b) the person’s age in years and the square of the variable age to control for non-linearity in the relation between age and traditional knowledge, c) the maximum school grade attained, d) the ability to speak Spanish, and e) a dummy variable that captures whether the person was interviewed in one or both survey rounds. Our model also includes two types of village-level controls. First, we used our remoteness index as a control. Second, we also included a set of dummy variables to control for village of residency. We also used village dummy variables to control for village attributes that most likely remained fix during 2000–2009 (e.g., physical infrastructure, resources availability). We clustered observations by village of residency to relax the assumption that individual observations are independent across villages. The procedure adjusts for the fact that

individuals might share more knowledge with other people living close to them and provides robust (and more conservative) estimates of variance around regression parameters. In additional analysis, we a) substituted the variable age by our seven decade of birth dummy variables and b) included both variables (age and decade of birth) in the model. Models including age, birth cohort, and survey period are largely used in economics, sociology, and public health to study secular changes (Fienberg & Mason, 1979; Rodgers, 1982; Borjas, 2005) as they allow one to estimate the effect of time while controlling for age and cohort effects – the first referring to the accumulation of knowledge over the life cycle (or aging) and the second to changes in knowledge between birth cohorts (Godoy et al., 2009a). We used STATA for the statistical analyses and R for the Monte Carlo simulations.

3. Results

For every decade of birth, people who completed the survey in 2000 had higher scores than people who completed the survey in 2009 (Fig. 2). The average number of plant uses reported by informants in 2000 was 27.28 (SD = 6.54, N = 476), whereas the average number of plant uses reported in 2009 was 22.62 (SD = 6.75, N = 678). For every decade of birth, differences were significant in a t-test comparison of means (P < 0.05). The largest difference was found among people born in the 1980s (t-value = 6.09, SE = 1.45), and the smallest among people born during the 1950s (t-value = 3.1, SE = 1.23). Data do not suggest a linear decrease in the number of

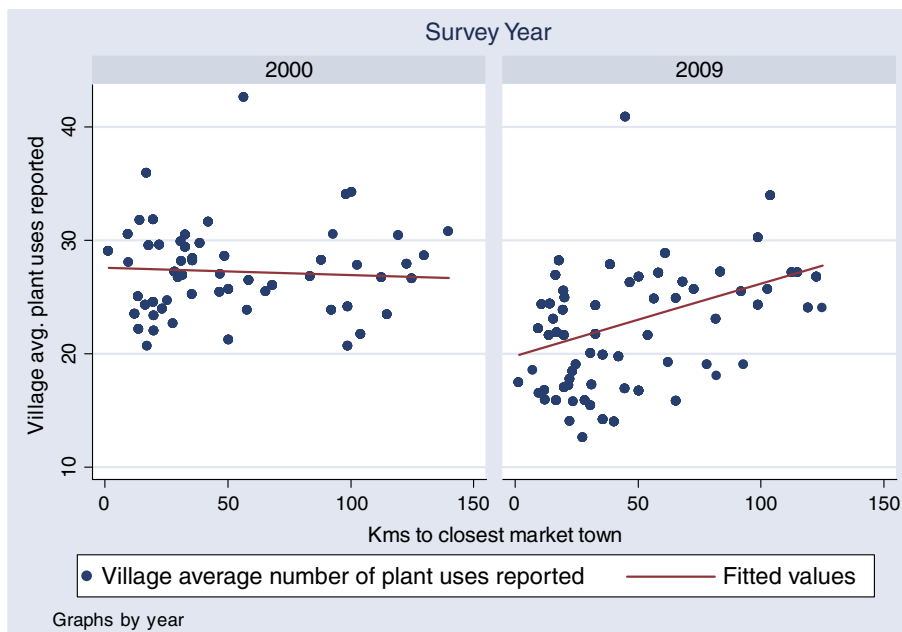


Fig. 5. Relation between village remoteness and average number of plant uses reported, by survey year.

Table 2
Results of Ordinary Least Square models predicting the rate of change on the logarithm of the number of plant uses reported.

	Model 1		Model 2		Model 3	
	Coef	CI	Coef	CI	Coef	CI
Year 2009	−0.204***	(−0.293, −0.114)	−.181***	(−0.267, −0.094)	−.203***	(−0.308, −0.099)
Age	0.009**	(0.003, 0.015)	^	^	.008	(0.002, 0.018)
Age square	−0.0001*	(−0.0001, −0.00001)	^	^	−.00001	(−0.0002, 0.00005)
Male	0.035	(0.010, 0.080)	.035	(0.009, 0.079)	.035	(0.009, 0.079)
Maximum education level	0.007	(−0.001, 0.014)	.007	(−0.0004, 0.014)	.007*	(−0.0002, 0.014)
Spanish	0.039	(−0.013, 0.090)	.037	(−0.012, 0.087)	.036	(−0.013, 0.086)
Remoteness	0.118***	(0.087, 0.149)	.119***	(0.086, 0.152)	.118***	(0.084, 0.151)
Interviewed twice	0.005	(−0.044, 0.054)	.001	(−0.047, 0.049)	.001	(−0.049, 0.047)
Decade of birth (1920 excluded category)						
1930s	^	^	−.094	(−0.228, 0.039)	−.099	(−0.258, 0.059)
1940s	^	^	−.032	(−0.171, 0.107)	−.037	(−0.265, 0.190)
1950s	^	^	−.071	(−0.184, 0.042)	−.064	(−0.318, 0.191)
1960s	^	^	−.047	(−0.158, 0.063)	−.012	(−0.315, 0.291)
1970s	^	^	−.077	(−0.195, 0.040)	−.005	(−0.352, 0.341)
1980s	^	^	−.153**	(−0.273, −0.034)	−.046	(−0.423, 0.332)
R ²	0.418		0.421		0.423	
N	1151		1151		1151	

Coef: Coefficient, CI: Confidence Interval. *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$. Ordinary least squares regressions with clustering by village of residency. ^=variable intentionally omitted.

plant uses reported across decades of birth either in the 2000 or in the 2009 samples. For example, in the 2000 survey, the average number of plant uses reported was lower in the 1930s cohort than in the 1940s cohort. The average number of plant uses reported was also lower in the 1950s cohort than in the 1960s cohort.

3.1. Random copying processes

According to our simulations, the chance of obtaining a decrease in the mean number of plant uses reported that is similar to the one perceived between the 2000 and the 2009 surveys is almost non-existent ($p < 0.0001$ for observed results, Fig. 3). For the diversity index, the comparison between observed data and simulation results also suggests that the chance of attaining a decrease in the diversity index that is similar to the one observed with our survey data is almost non-existent ($p < 0.0001$ for observed results, Fig. 4).

3.2. Plant uses and remoteness

In both surveys the average number of plant uses reported was largest in remote villages (Table 1). For each remoteness category, the average number of plant uses reported in 2000 was higher than the average number of plant uses reported in 2009 (all differences were statistically significant in a t-test comparison of means $P = < 0.003$). Differences in close villages were larger than differences in remote villages (6.67 more plant uses reported in 2000 than in 2009 in close villages versus 4.28 in remote villages). A Pearson correlation between the index of village remoteness and the average number of plant uses

reported showed a positive correlation in 2009 ($r = 0.3$, $N = 66$, $P = 0.01$) but not in 2000 ($r = 0.119$, $N = 58$, $P = 0.373$) (Fig. 5).

3.3. Rate of change

Results from Ordinary Least Square multivariate regressions with the logarithm of the number of plant uses reported as outcome variable and a dummy variable for *year 2009* as the main explanatory variable suggest that during 2000–2009 the Tsimane' experienced a significant decrease in the number of plant uses reported (Table 2). Irrespective of the remoteness of the settlement and of the individuals' age, sex, schooling, Spanish fluency, and participation in one or both surveys, people interviewed in 2009 reported approximately 20% less plant uses than people interviewed in 2000 ($p < 0.001$, 95% Confidence Interval = [−0.293 to −0.114]). Since the variable *year 2009* captures a nine-year period, assuming a linear change, our estimation suggests that the number of plant uses reported decreased by ~2.2%/year. This association was not altered if we substituted age by decades of birth (Model 2) or if we included both variables: *age* and *decade of birth* (Model 3), although the coefficient of the variable *year 2009* slightly decreased. From the control variables only *remoteness* showed a consistent and positive association with the number of plant uses reported.

To test whether those results were an artifact of methodological differences between both surveys (i.e., sampling strategy or more inquisitive enumerators in one of the rounds), we did three additional robustness tests. Robustness models resemble the regression model presented in Table 2, except for the changes explained below. First, we

Table 3
Robustness analysis: Results of Ordinary Least Square models predicting the rate of change on the logarithm of the number of plant uses reported.

Model	Subsample	Coef	95% CI	R ²	N
[1]	Males	−.224***	(−0.319, −0.129)	0.51	849
[2]	Females	−.092	(−0.211, 0.027)	0.32	302
[3]	People interviewed once	−.245***	(−0.362, −0.127)	0.47	881
[4]	People interviewed twice	−.123***	(−0.213, −0.033)	0.24	270
[5]	Close villages' residents	−.262***	(−0.412, −0.113)	0.48	419
[6]	Medium distance villages' residents	−.207***	(−0.353, −0.061)	0.39	407
[7]	Remote villages' residents	−.117	(−0.310, 0.075)	0.32	325

Coef: Coefficient of the variable *Year 2009*, CI: Confidence Interval. ***, $P \leq 0.001$. Ordinary least squares regressions with clustering by village of residency. Regressions include the same controls reported in Table 2.

run the regressions for the subsamples of men and women (Table 3, Rows [1] and [2]). In both models the variable *year 2009* shows the expected negative sign, but the coefficients differ in magnitude and statistical significance. Men interviewed in 2009 reported approximately 22% less plant uses than men interviewed in 2000 ($p < 0.001$), whereas women interviewed in 2009 reported only about 9% less plant uses than women interviewed in 2000. Furthermore, differences in the female subsample were not statistically significant. Second, we next ran our model using only the subsample of people who were interviewed only once (Row [3]) and then using only the subsample of people who were interviewed during both survey years ($n = 135 \times 2 = 270$) (Row [4]). We observe a 24% decrease in the number of plant uses reported by people interviewed once ($p < 0.001$), but only a 12% decrease by people who were interviewed in the two survey rounds ($p < 0.001$, 95% CI = $[-0.214$ to $-0.033]$).

In our last robustness test we separated the sample in the three remoteness categories (Table 3, Rows [5]–[7]). People living in villages close to market towns reported 26% less plant uses in 2009 than people living in similar villages did in 2000 ($P < 0.001$), representing a decline of $\sim 3\%$ /year. The difference was lower (21%, $P < 0.001$) for people living in villages in the medium category, and lowest and statistically non-significant (12%, $P = 0.221$) for people living in remote villages.

4. Discussion

We organize the discussion around the two main theoretical questions that motivated this research: 1) what is the rate of change of traditional knowledge in a contemporary indigenous society? and 2) what could be the drivers of such a change? We conclude by addressing the contributions of this work to cultural evolution theory and to policy-making.

4.1. Rate of change

Our results suggest that between 2000 and 2009, Tsimane' adults experienced a net decrease in the report of plant uses ranging from 9% (for the female subsample) to 26% (for the subsample of people living close to towns), equivalent to 1% to 3% per year. As those figures suggest, changes do not equally affect the sampled population: changes were more acute for men than for women and for informants living in villages close to market towns than for informants settled in remote villages.

We do not have similar data on rates of cultural change from other contemporary indigenous societies. Recent phylogenetic work investigating groups belonging to the Tupi language family in lowland South America suggests that, although there is a historical trend towards losing cultural features, cultural change has historically been very slow, on the order of only a few changes per 10,000 years (Walker, Wichmann, Mailund, & Atkisson, 2012). The findings presented here are not directly comparable to phylogenetic work, as our unit of analysis (number of wild plant uses reported) is less specific than the cultural traits examined in the work of Walker et al. (e.g. traditional warfare patterns, post-marital residence, presence of canoes, tattooing). However, it seems plausible to argue that the rate of change found in this work largely surpasses estimates derived from the study of past societies, which raises the issue of the drivers of change.

4.2. Drivers of change

Results from a Monte Carlo simulation show that the observed changes were not the result of randomness. When changes occur as a result of random copying, the probability of acquiring a new cultural trait for a given population is similar to the probability of losing one already known (as defined by Enquist et al., 2011). Since changes

observed in our data during the studied period of time exceed by far the variation of knowledge that could be expected to occur due to random drift, we could reject the hypothesis that random variations of knowledge are responsible for the observed decrease in the number of plant uses reported. The observed changes in plant uses reported could be then explained as a consequence of Tsimane' adaptation to the new economic, social, political, and environmental conditions influencing them.

The Tsimane' remained relatively isolated until the 1970s but they have since undergone a rapid process of acculturation and integration to the market economy that has rapidly transformed their economy and society (Godoy et al., 2009b). Over the last decades, the Tsimane' have increasingly engaged in wage labor and cash cropping (Reyes-García et al., 2012) and have replaced many plant-made items with market goods (Godoy et al., 2007). Recent changes, such as the establishment of schools or the election of political representatives to defend their interest, have also affected the traditional learning processes and the traditional leadership role of elders (Reyes-García et al., 2008). Furthermore, the arrival to the area of colonist farmers, logging companies, illegal loggers and cattle ranchers has also resulted in fast environmental degradation over the last few decades, especially in areas close to market towns (Gueze et al., 2013). Thus, Tsimane' adaptation to those new socio-economic, political and environmental conditions (new economic activities, learning system, political representatives, legal autonomy, and an increasingly degraded-environment) is likely to explain the observed changes in plant uses know.

This explanation also fits well with the fact that changes in levels of traditional knowledge do not affect equally the whole studied population. For example, the fact that changes are more acute among men than among women meshes well with the previous explanation, as Tsimane' men are much more likely to abandon their home villages in search of new economic activities than Tsimane' women. The explanation also fits well with the sharper decrease of knowledge in villages closer to market-towns than in remote villages, as people in remote villages continue to depend on their traditional knowledge to sustain their livelihoods, whereas people in closer villages have different economic opportunities and a more degraded environment that is becoming increasingly unsuitable for their traditional livelihood activities.

4.3. Contributions to cultural evolution theory

The research presented here provides more than an empirical case study on rates and drivers of cultural change among contemporary indigenous societies. At the methodological level, our research adds to the tool-kit of methods used to study cultural change, specifically to those commonly utilized by anthropological field-workers interested in cultural evolution. At the theoretical level, results from our research provide insights into individual-level processes that are responsible for population-level patterns of cultural change. Researchers have argued that cultural change occurs through different individual- and group-level innovation processes, different types of social learning processes, and different cultural transmission processes (Mesoudi, *in press*). Within this context, researchers have argued that new cultural variants can occur within one generation through individual innovation (Cavalli-Sforza & Feldman, 1981), but less attention has been paid to loss of cultural traits within a generation. Our analysis of a subsample of people interviewed twice indicates that, under rapidly changing socio-economic, political, and environmental conditions, cultural loss can occur within a single generation, and not only during the transmission process, as one generation neglects to transmit knowledge to the next generation as it has been previously argued (Aunger, 2000b; Casagrande, 2002; Reyes-García et al., 2009; Gomez-Baggethun et al., 2010).

4.4. Policy implications

Because traditional knowledge contributes to conservation (Gadgil, Berkes, & Folke, 1993; Turner & Berkes, 2006; Gomez-Baggethun et al., 2010), provides multiple benefits to the holders of such knowledge (e.g., McDade, Reyes-García, Leonard, Tanner, & Huanca, 2007), and partially encodes human cultural diversity (Maffi, 2005), researchers and policy makers have shown increasing concern for its loss. The research presented here provides a first estimate of the rate at which this process occurs in a contemporary indigenous society. Findings from this work might not be directly transferable to other societies but, as many contemporary indigenous societies are exposed to changing conditions similar to those described here (Godoy, Reyes-García, Byron, Leonard, & Vadez, 2005), our estimates could be taken as an indication of the general trend of cultural knowledge loss among contemporary indigenous societies.

Our research suggests that the Tsimane', and probably other contemporary indigenous societies, could be abandoning their traditional knowledge as they perceive that this form of knowledge do not equip them well to deal with the new socio-economic and cultural conditions they face nowadays. Policy-makers interested in the well-being of indigenous peoples should then assess what other forms of knowledge are substituting traditional knowledge and to what degree those other forms of knowledge actually contribute to improve the quality of life of contemporary indigenous peoples. Policy makers should also be concerned about the apparent parallel decline of the world's biological (Sutherland, 2003; Thomas et al., 2004), linguistic (Harmon & Loh, 2010), and cultural diversity.

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