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Authors: Bolton, Gary H., and McClaran, Mitchel P.

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Gary H. Bolton and Mitchel P. McClaran

Evaluating Sustainability of *Symplocos ramosissima* Harvest for Herder Huts

A Case Study Near an Upper-elevation Village in Nepal

Upper-elevation villagers in Nepal harvest large numbers of 5–10 cm diameter trees to construct itinerant herders' shelters. The harvest of these poles, as well as fuelwood and tree-leaf livestock fodder, may be altering upper-elevation forest structure and resource availability in Nepal. Near a village in west-central Nepal, we evaluated the sustainability of Symplocos ramosissima *poles harvested for herders' shelter construction by comparing estimates of harvest and replenishment rates under 4 scenarios of spatial distribution of harvest within 3 equal-area forest types: 1) harvest evenly distributed, 2) harvest only in forest type closest to area of hut construction, 3) harvest in two closest forest types, 4) harvest in each forest type proportional to recent use patterns, as deduced from the density of stumps of pole-sized* S. ramosissima. *Mean density ± SE of pole-size* S. ramosissima *was 375 ± 32 stems* ha^{-1}. *Tree-ring analysis of 24 pole-size* S. ramosissima *indicated a mean age of 35 years and a mean of 11 years to grow from 5 cm to 10 cm dbh. Comparisons of harvest and replenishment rates suggest that only harvest scenario 1 (even distribution) was sustainable. Harvest scenario 2 (closest forest type) and scenario 3 (two closest forest types) were unsustainable. Harvest scenario 4 (proportional to stump density) was sustainable in the two farther forest types, but unsustainable in the forest type closest to agricultural fields.*

Keywords: *Replenishment rates; indigenous resource use; spatial distribution of harvest; forest degradation; tree-ring analysis; Nepal.*

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Introduction

Resource sustainability is a growing concern in many aspects of the human–environment relationship, including human use of forests (Oliver 2003). There have been many efforts to define sustainability, with respect to various resources, system properties, and other values to be sustained (eg Aplet et al 1993; Callicott and Mumford 1997). For the purposes of this research, we consider resource sustainability to be maintained if the harvest rate does not exceed the rate of regrowth and replenishment.

More challenging than defining sustainability is devising methods for its assessment and management strategies for its achievement. Some assessments of forest resource sustainability use measurements of the resource base over time, attempting to assess whether resource depletion is occurring. For example, Pandit and Thapa (2004) assessed sustainability of harvest practices for several non-timber forest products in a central Nepal watershed using structured interviews of forest users regarding changes in resource type abundances over the previous 5-, 10-, and 20-year periods.

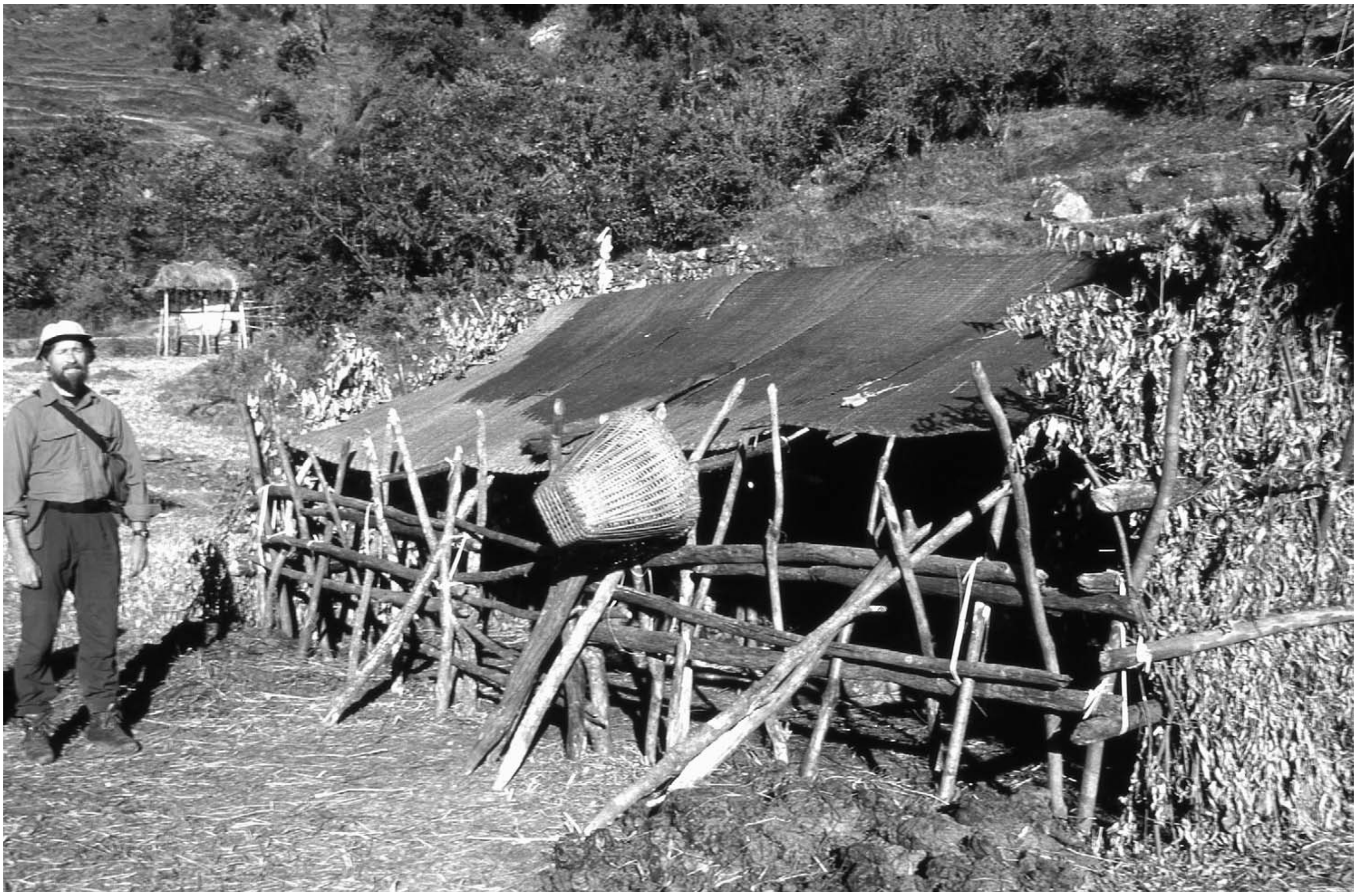
Another more objective approach to assessing sustainability of a forest resource is to compare harvest rate with the rate of regrowth or replenishment of that resource. Schwartz et al (2002) studied harvest rate and tree growth rate of *Pterocarpus angolensis* in Tanzania, to assess sustainability of harvest practices for construction and medicinal purposes. They measured densities of 5-cm interval size classes and used tree-ring increment cores to estimate the time required for trees to transition between size classes, and found that recruitment was insufficient to replenish the populations before the next harvest.

The spatial distribution of harvest is important because it can create areas where harvest exceeds a sustainable rate and other areas where sustainability is being achieved. For example, in the Indian Himalaya, Moench (1989) found that harvest of forest products was concentrated near the forest margin close to the village, resulting in unsustainable use only near the village while the larger portion of the forest was underutilized. Therefore, it is important to account for the spatial distribution of harvest and replenishment rates to identify areas where sustainability may be compromised.

The *goTh* system of agriculture

Across the southern slope of the Nepal Himalaya between 1700 and 2600 m, upper-elevation villagers practice the *goTh* (approximately pronounced "goat" with a hard "t") system of subsistence agriculture. Due to low fertility of upper-elevation agricultural soils, nutrients are added by keeping large herds of livestock on the fields for one to several weeks prior to planting. Most upper-elevation villages have access to areas of broadleaf forest, from which tree-leaf fodder is hand cut to feed the livestock while they are confined to the fields. While tending the livestock away from the village, herders reside in temporary shelters called *goThs*, constructed from poles and woven bamboo roof mats harvested from the nearby community forests (Figure 1). Most households use several *goTh* locations in an annual rotation, and dismantle and store the poles between uses.

FIGURE 1 First author beside herder's shelter. (Photo by Elise Pendall)



Objective

The objective of this research was to assess harvest sustainability of 5–10 cm diameter *Symplocos ramosissima* used for *goTh* hut construction, by comparing harvest rates with the rates of replenishment under 4 spatial distribution scenarios of that harvest. The 4 scenarios of spatial distribution assume:

1. Uniform harvest throughout the forest area;
2. Harvest restricted to the forest type closest to the agricultural fields;
3. Harvest restricted to the two forest types closest to the fields; and
4. Harvest performed throughout the entire forest in proportion to the spatial distribution of pole-size *S. ramosissima* stumps.

Study area

Chimkhola is a small village in west-central Nepal (Figure 2), located on a tributary of the Rahughat Khola (river), 53 kilometers northwest of Pokhara at 1770 m (28° 28′ 35″ N, 83° 31′ 20″ E). Chimkhola has a summer monsoonal climate, with a mean annual precipitation of 2700 mm and mean monthly temperatures ranging from 6°C in January to 29°C in June (Metz 1989).

Metz (1989, 1990, 1994) found that 84% of Chimkhola's 285 families engaged in the *goTh* system of resource use. The average *goTh* hut was 3.5 m × 7.0 m, with an additional narrow fenced area attached to the front (see Figure 1). The large size provided nighttime shelter for young livestock as well as the herder. The average family accessed 9 separate agricultural fields at disjunct locations, each suitable for a different crop type, thus requiring each family to use 9 sets of *goTh* poles. Stored poles remained functional for 6 years if protected from monsoon rains, but only 2 years or less if unprotected. On average, a family harvested 3.17 sets of *goTh* poles per year because only 4 sets of poles were stored in protected locations, one at their village home and 3 at stone huts on their lower fields (Metz 1994). Although some *goTh* poles were harvested from other species, the majority of poles harvested were *Symplocos*

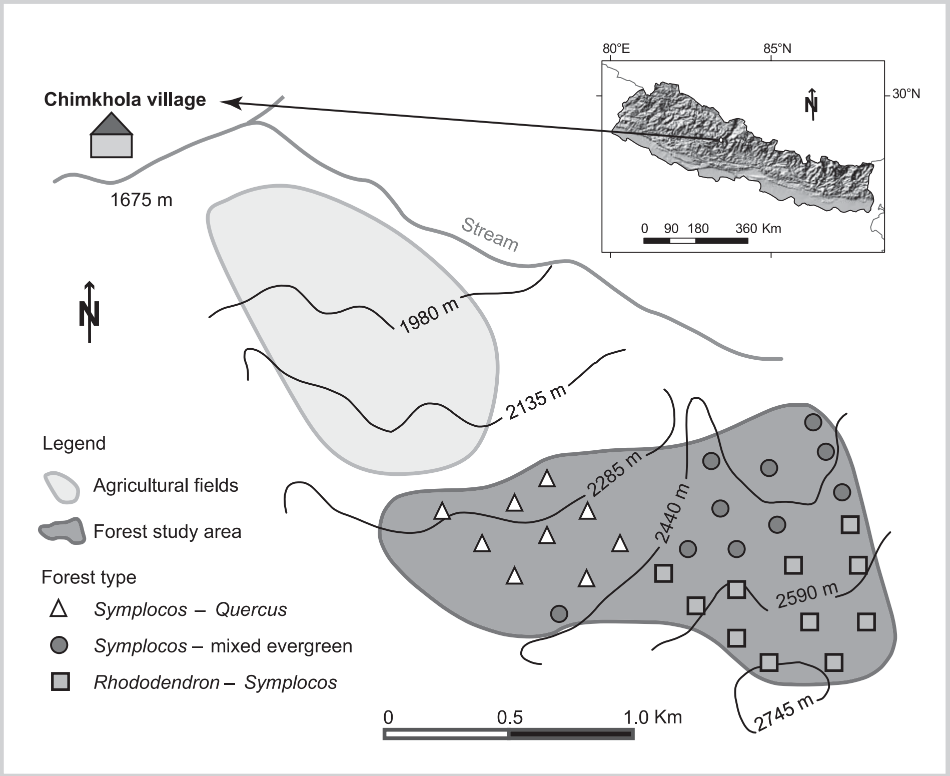


FIGURE 2 Map of Chimkhola, agricultural fields, and forest study area, showing locations of study plots (symbols) and their forest types. Herder's huts were distributed throughout the area indicated as agricultural fields. (Map by Gary Bolton)

ramosissima, due to its great abundance, characteristic straight stem, and low taper (Figure 3).

Our study area is a 150-ha forest southeast and upslope (2300–2800 m elevation) from the village, in which resource use is restricted by tradition to residents of Chimkhola. One third of Chimkhola's agricultural fields are located between our study forest and the village (see Figure 2; Metz 1989). *GoTh* poles used in those agricultural fields are harvested from this forest. Therefore, we interpreted that one third of the total *goTh* pole requirement for the entire Chimkhola community is harvested from our study forest.

Three forest types were identified in the study area (Figure 2), using Ward's minimum-variance cluster analysis of density data for 32 tree species (Bolton 2005). The *Symplocos–Quercus* type, dominated by the small tree *Symplocos ramosissima* and the large oak *Quercus lamellosa*, is closest to the agricultural fields (mean distance 1.2 km) and lowest in elevation. The *Symplocos*–mixed evergreen type, dominated by *S. ramosissima* with high abundances of *Lindera pulcherrima*, *Dodecadenia grandiflora*, *Rhododendron arboreum*, and *Machilus duthei*, is intermediate in distance from the fields (1.6 km) and in elevation. The *Rhododendron–Symplocos* type, dominated by *R. arboreum* and *S. ramosissima* with moderately high abundances of *D. grandiflora* and *Lyonia ovalifolia*, occurs farthest from the fields (2.0 km) and at the highest elevation. Each forest type occupies approximately one third of the 150-ha forest area (Figure 2).

Methods

Tree and stump densities

In 1997, pole-size *Symplocos ramosissima* trees of 5–10 cm diameter at breast height (dbh) and pole-size stumps in the study area forest were counted in plots, each 0.1 ha (20 m × 50 m). Plots were established at 200 m intervals along parallel transects across the forest. This regular dispersion of plots was intended to capture the maximum range of variation in forest structure and distance from agricultural fields (Mueller-Dombois and Ellenberg 1974; Husch et al 1982). Geostatistical analysis by variogram (SAS Institute Inc. 2001) did not detect autocorrelation at the spatial scale of distance between plots, allowing us to treat them as independent samples.

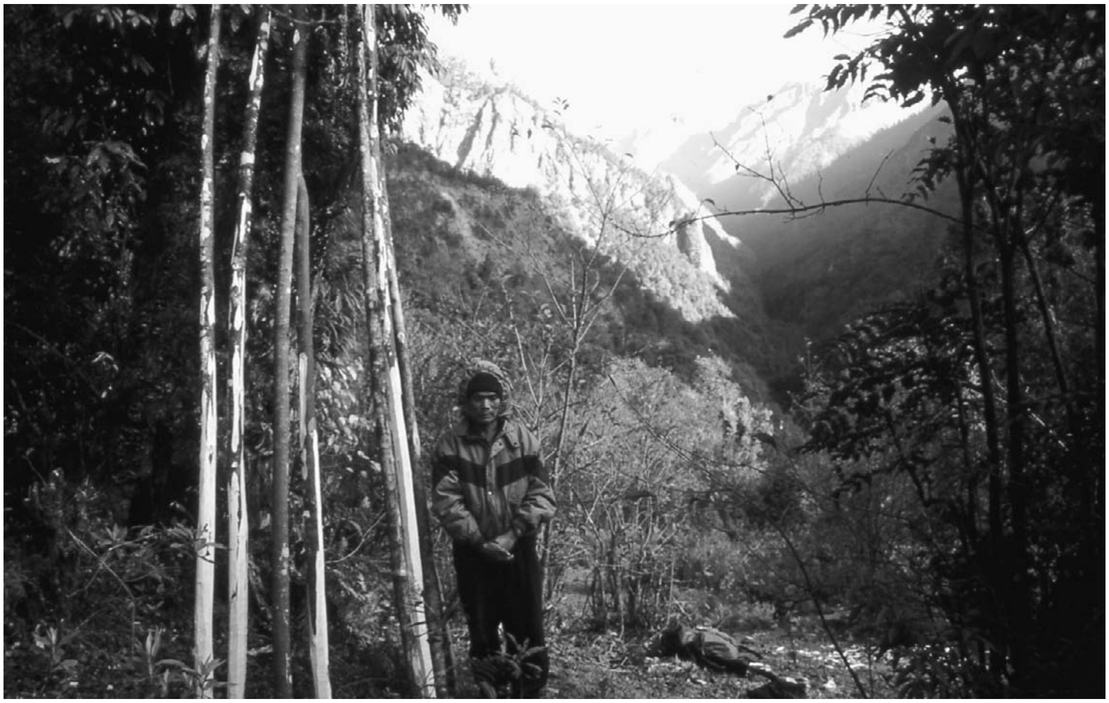
Mean densities of trees and stumps for the entire forest area were estimated from the mean densities in the 30 plots. Densities of trees and stumps for each of the 3 forest types were estimated from means of densities in the groups of plots within each forest type.

Harvest rates

We define harvest rate as: $\text{trees}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1} = ((\text{poles}\cdot goTh^{-1}) / (\text{poles}\cdot\text{tree}^{-1})) \times (goTh\cdot\text{year}^{-1}\cdot\text{family}^{-1}) \times (\text{family}\cdot\text{ha}^{-1})$.

We estimated $\text{poles}\cdot goTh^{-1}$ by averaging the number of structural poles used in 7 *goTh* huts, representing the size range of these huts. Poles are used as vertical supports (*gotcha*; ~4–5 cm diameter, 1.5–1.7 m long) placed at 25-cm spacing, horizontal poles (*gaaraalo*; ~6–8 cm

FIGURE 3 Field assistant Bo Bahadur Thapa beside harvested poles. (Photo by Gary Bolton)



diameter, 2–3 m long) placed at 3 heights across the wall, and posts and beams (*kaamo* and *bolo*; ~8–10 cm diameter and 2–3 m long) that support the roof of woven bamboo mats. After tying crossed poles with strips of split bamboo, herders fill in the wall framework with leafy tree branchlets or the leafy tops of bamboo stems. Because the small wall and fence vertical members were harvested from the sapling size class and from coppice stump regrowth in the shrublands surrounding agricultural fields, we based our estimate of pole-size tree harvest for *goTh* construction on the average requirement for medium and large poles.

We estimated 2 poles·tree^{-1} for *Symplocos ramosissima* plants of 5–10 cm dbh, where the length of stem >5 cm diameter provides poles of sufficient size for *goTh* construction. Interviews with Nepalese assistants support this estimate.

We used Metz's (1994) estimate of 3.17 *goTh*·year^{-1}·family^{-1} because it accounts for deterioration related to storage and the *goTh*·family^{-1} in the village. Our estimate of 0.53 family·ha^{-1} is based on Metz's (1989, 1994) assessment that 84% of Chimkhola's 285 households practiced the *goTh* system, and our 150-ha study area provided poles for 33% of the land area available for Chimkhola's *goTh* agriculture.

We estimated the actual harvest rate in each of the 3 forest types by adjusting the overall forest harvest rate (trees·ha^{-1}·yr^{-1}) by the proportion of total pole-size *Symplocos ramosissima* stumps occurring in each forest type. We compared stump density among the 3 forest types using analysis of variance (ANOVA). Stump density data satisfied the ANOVA assumptions of equality of variances (F-test) and normality (Kolmogorov-Smirnov tests; Sokal and Rohlf 1994).

Replenishment rates

We define replenishment rate as: trees·ha^{-1}·yr^{-1} = (pole-size trees·ha^{-1}) / (years spent in the pole-size class). This estimates the annual replenishment of pole-size *Symplocos ramosissima* based on the existing density of plants and the length of time individuals remain in that size class during growth.

To estimate the time spent in the pole-size class, we developed an age–size relationship using linear regression to estimate the time to grow from 5 to 10 cm dbh. Basal sections of 24 *S. ramosissima* trees between 5–10 cm dbh were sanded to 400-grit paper, and age was determined by ring count (Fritts 1976). Residual plots indicated homoscedasticity and a Kolmogorov-Smirnov test showed no significant departure from normality (Sokal and Rohlf 1994). While many evergreen tree species do not produce reliable annual growth rings, *S. ramosissima* rings were considered to be annual based upon anatomical details and cross-dating (Fritts 1976).

Mean replenishment rate for the entire forest area was calculated using the mean density of pole-size trees in the 30 study plots. Separate replenishment rates for each forest type were calculated using mean densities in the study plots located within those forest types.

TABLE 1 *Symplocos ramosissima* pole and stump densities, and harvest and replenishment rates among forest types near Chimkhola village, Nepal. Values in parentheses are one Standard Error of the mean (SE).

Forest type	Mean distance to agricultural fields (km)	Pole density (poles·ha^{-1})	Stump density (stumps·ha^{-1})	Harvest rate (trees·ha^{-1}·yr^{-1})	Replenishment rate (trees·ha^{-1}·yr^{-1})
Symplocos–Quercus	1.2	431 (35)	91 (21)	53.6	39.2
***Symplocos*–mixed evergreen**	1.6	454 (64)	46 (11)	25.3	41.3
Rhododendron–Symplocos	2.0	327 (61)	41 (13)	22.2	29.7
Total forest area	–	375 (32)	61 (15)	33.7	34.1

Sustainability and spatial distribution scenarios

We define sustainability as the positive difference between replenishment and harvest rates for each of the 4 scenarios of spatial distribution of harvest. For Scenario 1, spatially uniform harvest, we compared mean replenishment and harvest rates for the whole forest area. For Scenarios 2 through 4, we used the specific replenishment rates for each of the 3 forest types. For Scenario 2, harvest was confined to the forest type closest to the agricultural fields, occupying one-third of the total forest area. For Scenario 3, harvest was confined to the two forest types closest to the agricultural fields, occupying two-thirds of the total forest area. For Scenario 4, harvest in each forest type was held proportional to the distribution of stumps, and separate sustainability determinations were made for each forest type. Because the time since cutting and decay rate of stumps could not be determined, stump density does not provide an absolute measure of harvest rate. However, the relative densities of stumps in the 3 forest types were interpreted to indicate the relative harvest rates in those forest types.

Results

Tree and stump densities

Mean densities ± SE of pole-size *Symplocos ramosissima* trees·ha^{-1} and stumps·ha^{-1} for the whole forest area were 375 ± 32 and 61 ± 15, respectively (Table 1). Tree density was similar in the *Symplocos–Quercus* and the *Symplocos*–mixed evergreen forest types, and least in the *Rhododendron–Symplocos* forest type. Stump density was significantly higher in the *Symplocos–Quercus* forest type located closest to the agricultural fields than in either the *Symplocos*–mixed evergreen or the *Rhododendron–Symplocos* forest types (ANOVA, $p<0.1$; Table 1).

Harvest rates

We estimate a mean forest-wide harvest rate of 33.7 *Symplocos ramosissima*·ha^{-1}·yr^{-1} based on our empirical estimates of 40 ± 2 (SE) poles·*goTh*$^{-1}$, 2 poles·tree^{-1}, 3.17 *goTh*·year^{-1}·family^{-1} (Metz 1994), and 0.53 family·ha^{-1}. We use stump density values to estimate that 53%, 25%, and 23% of recent harvest occurred in the *Symplocos–Quercus, Symplocos*–mixed evergreen, and *Rhododendron–Symplocos* forest types, respectively. Apportioning harvest based upon stump densities, harvest rate in the *Symplocos–Quercus* type closest to the agricultural fields was more than twice that for the more distant forest types (Table 1).

Replenishment rates

We estimate replenishment rates of pole-size *Symplocos ramosissima* based on density divided by the number of years spent in the pole-size class. Our empirical estimate of 11 years to grow from 5 to 10 cm dbh is based on the age–size regression, (age (yr) = 19.7 + 2.23 dbh (cm); $r^2 = 0.30$ and $p = 0.006$) that estimates the average age of 5-cm and 10-cm trees to be 30.8 and 42 years, respectively. The replenishment rate (trees·ha^{-1}·yr^{-1}) varies among forest types in direct proportion to the density of pole-sized *Symplocos ramosissima* (Table 1).

Sustainability and spatial distribution scenarios

Sustainable harvest of pole-size *Symplocos ramosissima* for *goTh* structures occurs only under the assumption of uniform harvest rate across the entire 150-ha forest (Scenario 1), or in the two forest types farthest from the village if harvest rates are based on the spatial distribution of stumps (Scenario 4). In all scenarios where harvest is confined (Scenarios 2–4), non-sustainable harvest of pole-size *S. ramosissima* will occur in at least part of the forest (Table 2).

Discussion

Our findings support the suggestion that estimates of sustainable resource use must recognize spatial variation in the rates of harvest to identify areas of non-sustainable as well as sustainable use of resources. We found that estimates of sustainability of pole-size *Symplocos ramosissima* harvest were dependent on the spatial pattern of use and the extent of forest used to estimate *S. ramosissima* availability. When we used the spatial distribution of *S. ramosissima* stumps to estimate the ongoing spatial distribution of harvest pressure (Scenario 4),

TABLE 2 Replenishment and harvest rates (stems·ha^{-1}·yr^{-1}), and sustainability determinations (replenishment–harvest) for the harvest of pole-size *Symplocos ramosissima* under 4 scenarios that differ in the spatial distribution of harvest. Positive values in the Sustainability column indicate a sustainable harvest rate.

	Replenishment rate (R)	Harvest rate (H)	Sustainability (R–H)
Scenario 1			
Spatially uniform harvest	34.1	33.7	0.4
Scenario 2			
Harvest only in *Symplocos–Quercus* forest type (closest to agricultural fields)	39.2	101	–61.8
Scenario 3			
Harvest only in two forest types closest to agricultural fields (*Symplocos–Quercus* and *Symplocos*–mixed evergreen)	40.2	50.6	–10.4
Scenario 4: Harvest spatially proportional to distribution of stumps — actual harvest pattern			
Symplocos–Quercus forest type (53% of stumps)	39.2	53.6	–14.4
Symplocos–mixed evergreen forest type (25% of stumps)	41.3	25.3	16
Rhododendron–Symplocos forest type (22% of stumps)	29.7	22.2	7.5

we found harvest rates were unsustainable in the forest type closest to the agricultural fields, but sustainable in the more distant forest types. However, when we ignored spatial variability, we estimated a very marginal sustainable rate of harvest across the entire forest. Any spatial variation in harvest, such as confinement to only one or two forest types (Scenarios 2 and 3) resulted in unsustainable harvest rates in those forest types.

We have great confidence in our estimates of pole-size tree and stump densities, which were derived from a large, plot-based data set. However, there are several potential sources of error in our estimates of harvest and replenishment rates. Accuracy of harvest rates is dependent upon several factors. The estimate of poles·*goTh*$^{-1}$ assumes the 7 huts selected for pole enumeration were representative. Our estimate of poles·tree^{-1} is dependent upon interviews of local field assistants. The estimate of *goTh*·year^{-1}·family^{-1} comes from Metz (1994) interview data regarding the number of agricultural field areas on which the average family constructs huts and the number of years poles remain useable. Our estimate of family·ha^{-1} relies on Metz's (1994) data regarding the number of families in Chimkhola and the percentage which practice *goTh* agriculture, the estimate that our forest study area provides poles for one third of the total agricultural area, and the assumption that because each family has their herds on these fields for part of the year, our forest area supplies one third of the total community demand. Accuracy of replenishment rates is dependent upon our estimates of density and the number of years spent in the pole-size class and our approach assuming that density divided by growth rate yields recruitment. Our estimate of growth rate depends on whether the 24 selected trees were representative of trees throughout the forest and whether their tree ring widths accurately reflected their rate of growth. Inaccuracies in one or more of these estimates could affect the evaluation of sustainability. However, we feel confident that our estimates of sustainability are representative of the decrease in harvest pressure at greater distances from agricultural fields, and the decreased likelihood of sustainable harvest nearer the agricultural fields.

Future sustainability may also be affected by other factors. It is possible that local human population growth may increase harvest pressure. However, social changes and changes in agricultural practices may reduce forest product harvest. Khanal and Watanabe (2006) documented abandonment of 47% of marginal upland agricultural land near the village of Sikles, 75 km east of Chimkhola. Factors contributing to abandonment included outmigration of some families to the lowlands and a shortage of local labor, as more village men take outside wage-earning jobs and more children attend school. With continued forest resource depletion in the Chimkhola area, with some outmigration to the lowlands, and with outside earnings integrating other Chimkhola households into the larger market economy, local agricultural intensity and demand for forest resources could decrease.

Despite any shortcomings of our of approach, our results agree with patterns observed by Moench (1989) near a village in the Indian Himalaya, where concentration of harvest near the closer forest margin resulted in resource depletion and impaired recruitment and replenishment. Our results are also in accord with reports of Chimkhola village elders (Metz 1994) that the degraded shrubland below the present forest margin was a tall forest of *Quercus lamellosa* several decades ago. It appears that a process of forest degradation near the forest margin began with intensive fodder lopping of *Quercus lamellosa* decades ago, and is now continuing through intensive pole harvest of *Symplocos ramosissima*.

Epilogue

During most of the decade since these field data were collected, guerilla activities of the Maoist rebellion made this part of Nepal unsafe for travel by foreign researchers. Observations in October 2007 by a returning Chimkhola native indicate that more young people have left the village to work in other countries (Som Pun, personal communication, 13 August 2008). Money remitted to Chimkhola families allows them to buy food and goods brought in from the outside market economy, reducing these families' dependence on subsistence agriculture and herding. Fewer fields under cultivation and smaller livestock herds result in fewer *goTh* shelters being constructed and reduced harvest of forest products. Despite this trend in reduced use of *Symplocos ramosissima* for *goTh* shelters, our findings of spatially explicit sustainability would predict that unsustainable harvest rates may persist in areas closest to agricultural fields even though the number and extent of those fields may have declined.

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AUTHORS

Gary H. Bolton
1169 Apache Drive, Laramie, WY 82072, USA.
ghbolton@gmail.com

Mitchel P. McClaran
School of Natural Resources, The University of Arizona, 325 Biological Sciences East Building, Tucson, AZ 85721, USA.
mcclaran@email.arizona.edu

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