Chapter Two

Harvest, Consumption, and Availability of Woody Plant Resources

Abstract

In this chapter, I assess the harvest and consumption of woody plant resources at a small (10 households) and relatively recent (~100 yrs) Sherpa settlement in the Temperate Sikkim-East Nepal Himalaya, and I investigate how these harvests have impacted availability of forest resources near the village. Households annually consume 12.2 metric tons of felled fuelwood, 1860 kg of tree fodder, 45 m^3 of forest litter, and ~690 culms of bamboo. Consumption is sometimes correlated with household wealth, size, or number of livestock, but frequently not. Preferred fuelwoods are *Quercus lamellosa*, *Quercus oxyodon, Myrsine semiserrata*, and *Viburnum erubescens*, but average-ranked *Alnus nepalensis*, *Lyonia ovalifolia*, and *Rhododendron arboreum* account for 87.5% of fuelwood consumed. *Michelia kisopa* is the primary timber species. Preferred tree fodder species are *Schefflera impressa, Ficus neriifolia*, *Persea* spp.*, Michelia kisopa*, and *Litsea elongata*. Woody plant species that regenerate quickly in relation to harvest rate are available closer to the village: pollarded stems are harvested at an average distance of <200 m, felled fuelwood 284 m, leaf litter 320 m, tree fodder 475 m, timber 550 m, and bamboo 1300 m. Felling of large late-successional trees for timber or fuelwood opens mature forest canopies, increasing the abundance of pioneer tree species. Harvesting selected size classes of trees distorts the natural age distribution of stands, compromising their future regenerative capacity. Livestock grazing exacerbates these impacts by limiting reestablishment of seedlings. I suggest ways to lessen the impact of woody plant harvest and increase the availability of high-value resources, but many economic, institutional, and cultural obstacles must be

overcome to successfully implement them.

Introduction

Himalayan agroecosystems are highly dependent on inputs of plant biomass from nearby forests (Rhoades and Thompson 1975, Guillet 1983, Pandey and Singh 1984, Orlove and Guillet 1985, Marten and Saltman 1986). The greatest demands are for livestock fodder (Mahat et al. 1987a) and mulch (organic fertilizer, Metz 1990). Large quantities of biomass are also harvested to satisfy household needs for fuel and shelter. Wood is the principal cooking and heating fuel in the Temperate Sikkim-East Nepal Himalaya (TSENH), as it is throughout most of the developing world (Openshaw 1978).

Current practices for cooking and crop fertilization are energy-inefficient (Singh et al. 1984, IARC 2010). Moench and Bandyopadhyay (1986) consider energy inefficiency, human population growth, and a dependence on forest resource inputs the root causes of the "nibble effect," the gradual "rolling back" of the forest perimeter around Himalayan villages. As the forest perimeter recedes, high-value forest resources become available only at increasingly distant locations. Households must allocate greater time and effort to harvest them, or turn to less desirable substitutes. The primary mechanism underlying Moench and Bandyopadhyay's nibble effect is human interference with the natural regenerative processes of woody plants (Metz 1998, Stainton 1972), by felling, lopping, and grazing them faster than they are naturally replaced.

The objectives of this chapter are to investigate the harvest and consumption of wild woody plants, assess how household composition influences resource selection and consumption, and assess the impact woody plant harvest has on the availability of forest resources.

The annual cycle of forest use in the TSENH is strongly influenced by seasonal climates and the seasonal demands of agropastoral production. Forest activities are generally timed to avoid adverse environmental conditions and coincide with slack times in agricultural production, during periods of mild climate just prior to and following the summer monsoon (March-May and October-November). Most people, other than livestock herders, avoid the forest during the summer monsoon, when demands for agricultural labor are highest, due to torrential rains, slippery footpaths, and an abundance of terrestrial leeches (Hirudiniformes) and biting flies (Ceratopogonidae). In winter, forest activities are curtailed by snow, temperatures below 0º C, and the seasonal presence of Asian black bears (*Solenarctos thibetanus*).

The assortment of woody plant species used as felled fuelwood varies from village to village, depending on species composition of local forests and the degree of forest degradation. Most high-ranking fuelwood species are slow-growing, and therefore less accessible near older or larger villages or where goat herding or swidden agriculture are practiced.

Timber is harvested primarily for local use, to construct homes, temples, livestock sheds and bridges. In Midland Nepal, the annual per capita timber requirement is estimated to range from ~0.05 to 0.10 m^3 (Mahat et al. 1987a). Commercial logging occurs in some areas of Sikkim, West Bengal, Bhutan and Arunachal, but is beyond the scope of this study.

Most traditional-style houses and livestock sheds in the TSENH are constructed from rough-hewn pole timbers, bamboo, and tree stems (Kleinert 1983, Fig. 2.1). They are relatively easy and inexpensive to construct, but only last a few years in the region's monsoon climate. Wealthier families construct houses from sawtimber and stone (Fig. 2.2). These are relatively expensive to build, and last up to 60-80 years (Mahat et al. 1987b), but require specialized milling, carpentry, and masonry skills. Sawtimber is used to make posts, beams, rafters, joists, floor planks, and window frames. In rural Nepal, ~4.8-7.5 m^3 of timber are required to build an average timber-and-stone house (Metz 1989a). In southern Sikkim, construction of a new house requires 5-7 m^3 of lumber from 7-10 trees measuring 29-40 cm DBH (diameter at breast height, Sundiryal and Sharma 1996).

It is common practice worldwide to use tree fodder (leafy branches freshly cut from trees) to feed livestock (Singh 1982, Akkasaeng et al. 1989, Paterson et al. 1998). In the TSENH, tree fodder, or *dhAle ghA˜s* (N. "toppled" fodder), is provided to stall-fed livestock in winter (December and May, when cropland fodders are in low supply) and to free-ranging livestock throughout the year. In Midland Nepal, recorded annual household consumption of tree fodder ranges from 115-142.4 *bhAri* (N. person-loads)/yr (Mahat et al. 1987b, Metz 1989a).

Bamboo is an important construction material throughout Asia. In the TSENH, it is used to construct houses, sheds, furniture, baskets, water jugs, tongs, and other utensils (Seeland 1980, Shrestha 1989). The demand for bamboo is so great relative to the supply that harvest is often controlled by local communities or government regulations, most commonly by restricting harvest to a brief period in autumn.

By South Asian standards, Himalayan communities are relatively egalitarian with regard to labor roles. Nonetheless, among Sherpas and Rais, tree felling, wood working and livestock handling are done primarily by men, whereas planting, weeding, and harvesting crops are done primarily by women (McDougal 1979, Fürer-Haimendorf 1964, Brower 1991). Labor roles of Sherpa women are more broadly defined than those of Sherpa men, as evidenced by the frequency women, not men, manage households single-handedly.

Methods

Study Area

The Chitre study area is described in detail in Chapter 1. Chitre Village consists of 10 Sherpa households (Fig. 2.3) clustered around Phinchho Norling *Gomba* (S. Buddhist temple, Fig.

2.4). The residents of Chitre are the principle day-to-day users of the local "community" forest, although some people from other nearby villages (Fig 1.3) use it seasonally to graze itinerant livestock herds, hunt, and harvest minor (alternative) forest resources (especially bamboo) and pole timber (infrequently). Since about 1995, permits must be purchased to graze livestock or harvest economically valuable resources from the forest (Chapter 1, Metha and Kellert 1998).

Data Collection

I collected most sociological data as an observer-as-participant (Gold 1958), using structured and casual interviews, household monitoring, participant observation, and informal observation (Pelto and Pelto 1978). I conducted interviews with three types of informants: heads of households, village elders, and groups of "resource specialists" who were recognized by other residents as having special knowledge of forest resources. At the onset of the study I interviewed the head of each household to determine: 1) gender, age, and residency patterns of household members, 2) size and number of household dwellings, hearths and livestock sheds, 3) household cropping patterns, 4) numbers and kinds of household livestock, 5) locations of household pasturage, 6) spatial and temporal patterns of forest resource harvest, 7) species preferences for woody plant resources, and 8) preferences for resource harvest locations. At the end of the study, I asked these questions again to check whether earlier responses had been guarded or if circumstances had changed. Only the number of people and livestock at some households changed during the study period, and not greatly, so I based all analyses on initial responses. The ratio of men and women interviewed was approximately equal, although at some households the husband and wife responded jointly.

I interviewed village elders about the oral history and traditions (legends) of the village, and to establish arrival dates for various technological innovations. I interviewed a resource specialist group, comprising Sherpa and Rai men, to ascertain local knowledge of the ecology and use of woody plant species. Interviews with elders and resource specialists were conducted with groups rather than individuals in order to facilitate consensus responses. I assessed the relative wealth of village households by surreptitiously interviewing four representative householders. Each person ranked village households according to his or her personal assessment of relative household wealth.

I sampled household consumption of fuelwood, tree fodder, forest litter and bamboo on a monthly basis between August 1993, and July 1994. I initiated household monitoring after I resided in the village for five months, giving residents time to become at ease with me and the objectives of the study.

I recognized three general types of fuel for the purposes of this study: 1) felled fuelwood (N. *dAura*), cut either dead or alive, 2) gathered fuelwood (N. *suka dAura*), and 3) *jhikra* (N.), woody debris and crop residues. I sampled the consumption of felled and gathered fuelwoods monthly, with a modified version of Fox's (1984) weight survey technique, which entails measurements taken over a three-day period. On the first day, I asked the head of a household to gather an amount of fuelwood that was somewhat more than s/he anticipated using the following day and place it into a large basket. The species of each piece of fuelwood s/he selected was recorded as it was placed into the basket. The basket was then weighed and set aside. On the second day, the household hearth was fueled with wood from the basket only (plus an unrecorded amount of *jhikra*). At the end of the second day, all unused fuelwood, including unburned pieces remaining in the hearth, was gathered back into the basket. On the third day, the unburned portion of the set-aside fuelwood was weighed. The amount of fuelwood consumed was calculated as the difference in weight of the set-aside fuelwood before and after use.

The weight of fuelwood varies greatly with moisture content. To correct for variation in moisture content, I conducted field tests to determine the percent weight loss by green-cut fuelwood after it had been dried over a cooking hearth for 32 days. I determined the volume of the samples by displacement of water. Based on the results of this test (see Results), if a householder indicated fuelwood was "very moist," I reduced the weight by 30%, and 15% if it was said to be "moist." Similarly, if it was said to be "dry," I increased the weight by 15%, and 30% if it had been dried over a hearth.

I assessed household consumption of tree fodder, cropland fodder, forest litter and bamboo in conjunction with monthly fuelwood monitoring. On monthly sample days, I asked household respondents how many *bhAri* of tree fodder, cropland fodder, forest litter and bamboo was brought to the household on the preceding day. For the purposes of this study, "tree fodder" consists of leafy branches and "cropland fodder" consists of cropland weeds or corn stalks. Monthly monitoring proved to be an unsatisfactory method for measuring household tree fodder and bamboo use because these resources were harvested only sporadically. I therefore based consumption estimates for tree fodder, forest litter, and bamboo on recall interviews conducted at the end of the study, during which heads of households estimated the total number of *bhAri* of each resource harvested during the previous harvest season. Interviewees used several memory devices to recall these quantities, including the number of bamboo mats (N. *chitra*) constructed and the number of baskets of mulch used to fertilize potato fields.

I assessed the availability of high-value woody species in ten 9-ha plots distributed along a distance/disturbance gradient extending out from the center of the village to a site too distant (~2 km) and too rugged for normal use by humans or livestock (Fig. 2.5). Within each 9-ha plot, I established 36 evenly-spaced sampling points (at intersections of a 50 m x 50 m grid) and sampled twelve woody plants >1.5 m height at each point using the point-centered-quarter method (Cottam and Curtis 1956). For each sample tree, I recorded species, evidence of lopping, and the presence of multiple stems. I also measured bamboo cover (all species) along 20 m of tape extended across each sampling point. Vegetation sampling methods are described in detail in Chapter 4.

Data Analysis

I use standard descriptive statistics to characterize household composition and resource consumption. I use Spearman rank correlation (Zar 1996) to test for correlations between household composition, resource consumption, resource availability, and quality rankings of resources using. I use the Spearman test because the number of samples is small (n = 10 households), some data are categorical (e.g., fuelwood quality rankings), and some variables are co-linear (e.g., household wealth and cultivated land). I use the student t test (Zar 1996) to test for differences in household resource consumption. For reporting fuelwood consumption, residency is measured in person-days, the number of full-time residents, seasonal residents, laborers and guests served a cooked meal on fuelwood sampling days. All statistical analyses are performed with the computer program StatMost (DataMost Inc., Salt Lake City), and I consider all statistical tests significant at $P \leq 0.05$.

I develop a list of high-value woody plant species based on rankings by local informants, and I assess their availability by analyzing relative frequency at increasing distances from the village (<100 m, 100-300 m, 300-500 m, 500-900 m, 900-1200 m, 1200-2100 m). I report results in percent frequency rather than absolute frequency, because the spacing of plots was uneven in the field (Fig. 2.5), the width of distance categories varied, and the number of plots per category ranged from 1-3.

Results

The age and wealth characteristics of Chitre households (1993-1994) are summarized in Table 2.1. Household size ranges from 1-7 adults (>18 yrs) and 0-7 children (<18 yrs). Six residents (adults and children) spent most of the year away from the village, herding itinerant *chau˜ri* (N. cattle-yak hybrid) herds, and three young men spent time in Kathmandu in pursuit of wage labor in the trekking industry.

Chitre's seasonal calendar of forest use (Fig. 2.6) is typical of communities in the broadleaf zone of the TSENH, with primary periods of forest use occurring in March-May (after crops are sown and before heavy monsoon rains) and October-November (after monsoon precipitation has ceases).

Fuelwood

There are three general methods of fuelwood harvest at Chitre: gathering, splitting dead and down, and green-felling. Gathering is the simplest, and consists of gathering dead branches and twigs from pastures and fallow swiddens near the village. Usually women or children harvest fuelwood in this manner, particularly when household stores of better quality fuelwood are low (Fig. 2.7).

Most fuelwood used for household hearths originates from larger trees which have fallen naturally or are green-felled. Dead and down splitting consists of cutting and splitting dead trees that have toppled to the ground naturally. Dead and down splitting takes place throughout the dry season (September-April), and the resulting wood requires relatively little drying before use. Green-felling is generally done in spring (March-May), after crops are sown and before heavy monsoon rains begin (Fig. 2.6). Trees are felled, and the split wood is stacked to dry at the harvest site (Fig. 2.8). Preferred trees have a single trunk and large branches, which maximize fuelwood yield while minimizing splitting effort. At Chitre, clusters of short-stature trees, especially *Rhododendron arboreum*, are sometimes clear-cut all at once.

Preferred felling sites are up slope from the village, near a good trail, and adjacent to a level working area. Felling and splitting are normally done by men, and are sometimes hired out to wage- or exchange-laborers. After drying, felled fuelwood is carried to the village, sometimes by women or children, and stored under awnings or in small woodsheds. Individual pieces of fuelwood are dried again just prior to use by leaning them against a south-facing wall or placing them on a rack over a hearth. Since about 1995, village residents are required to purchase a permit from the Local Community Forest User Group Committee to legally fell green trees (Metha and Kellert 1998).

Chitre households report distinct preferences for fuelwood species. Table 2.2 indicates consensus rankings for common fuelwood species, according to criteria suggested by household informants. First-ranked species are, in order of preference, *Quercus lamellosa*, *Quercus oxyodon, Myrsine semiserrata*, and *Viburnum erubescens*. In total, eleven species were used to fuel household hearths during the period of household monitoring (Fig. 2.9). Only 20 of the 62 woody species recorded at Chitre (Appendix 1.2) are considered to be of sufficient quality (average or better, Table 2.2) to use in household hearths.

Stated preferences for fuelwood species are not reflected in the proportions actually used however (Fig. 2.9), because some less-desirable species are easier to collect and process. Most fuelwood consumed at Chitre (87.5%) consists of three average-ranked species: *Alnus nepalensis* (36.9%), *Lyonia ovalifolia* (18.3%), and *Rhododendron arboreum* (14.5%). The only first-ranked species consumed during the monitoring period were *Viburnum erubescens* and *Quercus lamellosa,* which together account for only 7.2% of the fuelwood used. Third-ranked species account for 5.3%. The most frequently used species are disturbance-tolerant species that either are fast growing (*Alnus nepalensis*, *Lyonia ovalifolia*) or have relatively dense wood (*Lyonia ovalifolia, Rhododendron arboreum*).

The proportions of fuelwood species consumed vary by household. Use of first-ranked species is positively correlated (marginally) with the number of full-time household residents (r_s = 0.61, df = 10, P = 0.06), and use of low-ranked species is negatively correlated with wealth (r_s = -0.66, df = 10, P = 0.03) and total annual fuelwood usage (r_s = -0.74, df = 10, P = 0.02).

Cooking hearths (N. *chulli*) consist of three oblong stones planted upright in an earthen floor in tripod fashion (Fig. 2.10). There is no chimney or flue; smoke eventually exits dwellings through cracks and other openings. Because they are open on all sides, they are energy-inefficient and release unhealthy combustion byproducts into the indoor environment (IARC 2010). Fire is used sparingly however, usually only for the purpose of cooking meals (two per day), distilling alcoholic spirits, or heating kitchen-waste gruel (N. *ku˜do*) to feed livestock (especially milch stock). Cooking fires are only occasionally prolonged for comfort, especially in winter and when entertaining guests. Smoldering fires are occasionally lit in livestock barns (N. *bhArke*), in summer to repel biting flies and on cold nights to provide warmth for young or delicate livestock.

Village-wide, 72% of fires in household hearths (n = 140) are made from felled fuelwood (green-felled or dead and down) and 28% from gathered fuelwood. In livestock sheds (n = 58), 52% percent of fires are made from felled fuelwood, 29% from *jhikra,* and 21% from gathered fuelwood. Eighty-two percent of felled fuelwood is from dead and down trees, and 18% is from green-felled trees. *Jhikra* was added to 7% of cooking fires and 19% of fires in livestock sheds (to repel biting flies). During the monsoon, highly combustible maize “cobs” or bamboo scraps are used to ignite damp fuelwood. Dry cobs are added to 5% of cooking fires and 3% of fires in livestock sheds, primarily in May and June when the maize crop is being processed. Less than ~0.1 m^3 of cobs is used on each occasion. Bamboo scraps are added to just 2.0% of fires.

Under field conditions, green-cut fuelwood has the maximum moisture content and hearth-dried fuelwood has the minimum. Average weight loss of green-cut (very wet) fuelwood dried over a cooking hearth is 55% (Table 2.3). Because this amount of weight loss, roughly 60%, is the maximum possible under field conditions, I feel justified in standardizing for moisture content by reducing the weight of wood reported to be "very wet" by 30%, and increasing the weight of hearth-dried wood by 30%. The moisture content of air-dried wood lies in the middle of this range (average), so no weight correction is necessary.

On average, households consume 33.5 kg of fuelwood per day over a twelve-month period, or 12.2 metric tons annually (standardized to air-dried moisture content). Hearth-dried equivalents are ~23.5 kg/day and ~8.56 metric tons/yr (or 14.3 m^3/yr, assuming 600 kg/m^3, Fox 1984). Per capita fuelwood consumption for full-time household residents averages 9.0 air-dried kg/day (6.3 hearth-dried kg/day), or 3285 air-dried kg/yr (2300 hearth-dried kg/yr or 3.8 hearth-dried m^3/yr). Fuelwood consumption varies by season (Fig. 2.11). It peaks in January, when it averages 42.2 air-dried kg/household/day, and declines to nearly half that amount in July-August, when average consumption is 23-29 air-dried kg/household/day. Monthly consumption rates are significantly higher during the colder half of the year than the warmer half (September-February vs. March-August, $t_{0.05} = 3.27$, df = 10, $p < 0.01$).

Fuelwood consumption varies between Chitre households by as much as 59% (Table 2.4). Monthly household consumption is not correlated with household wealth, numbers of residents and visitors, frequency of alcohol brewing, or number of hearths. Annual per capita fuelwood consumption (kg/full-time resident/yr) is negatively correlated, although insignificantly, with the number of full-time residents (r_s = -0.59, df = 9, P = 0.09) and numbers of household person-days (r_s = -0.63, df = 9, P = 0.07). Once-a-month sampling proved to be too infrequent to assess the influence of brewing frequency on fuelwood consumption because brewing occurs too sporadically.

Households travel an average of only 284 m (SD ≈ 150, n = 10), or about 5 minutes walking time, to harvest felled fuelwood. Within 100 m of village center, average-ranked fuelwood species are much more abundant than either high- or low-ranked species (65% versus 10% and 20% of total tree basal area, respectively, Fig. 2.12). A few large *Quercus* trees that occur in this zone are not available for fuelwood because they maintained for tree fodder production. At 100-500 m distance, where most fuelwood is currently harvested, high- and low-ranking species become more available with distance, peaking at 300-500 m and 500-900 m, respectively. Average-ranked species become less available with distance in this zone, reaching minimum availability (44% of total basal area) at 300-500 m. Beyond 500 m, high-ranked species fluctuate between 12-26% of total basal area, whereas average-ranked species increase and low-ranked species decrease (Fig. 2.12).

Timber

Timbers used to construct traditional bamboo dwellings are usually *Symplocos* spp. and *Eurya* spp., fast-growing pioneer species that are straight, easily hewn, light to carry, and readily available in secondary forest. The main stem is rough-hewn into square timber with an adz. Timbers (N. *kATh*) used for more modern and expensive timber-and-stone houses are rip-sawn from large-diameter hardwoods (Fig. 2.13). Some men at Chitre are capable wood workers, but experienced tree fallers and carpenters are hired from other villages for larger projects. Felling and ripping take place in autumn (Fig. 2.6).

The most desirable timber trees have a single, straight, flawless, trunk, and are of sufficient height and girth to provide the timber required for a particular job. At Chitre, the principal species used for sawtimber are *Michelia kisopa* and *Castanopsis hystrix*, but species preferences depend on the application. For uses where wood will remain cold and wet due to shade or contact with the ground, preferred species are *Castanopsis hystrix*, *Persea* spp., *Michelia kisopa,* and *Litsea elongata* (in order of preference). *Castanopsis hystrix* is also used to make roof shakes. For uses where decay is less likely, the order of preference is *Michelia kisopa, Persea* spp., and *Castanopsis hystrix*. *Alnus nepalensis* and *Symplocos* spp. are also acceptable where decay is less likely, but they are considered weak and prone to decay. For load-bearing posts and beams, the order of preference is *Michelia kisopa*, *Persea* spp., *Castanopsis hystrix*, *Acer campbellii*, and *Alnus nepalensis*. *Quercus* spp. are considered very strong, but are not favored because they are "difficult to drive nails through" and "warp and crack" over time. *Michelia kisopa* is favored above all other timber species for its durability, lack of cracking or warping, ease to work, and rich color (also see Cowan 1929).

I did not attempt to estimate annual household timber consumption, because dwellings are built or repaired infrequently. Informants estimate fewer than 60 large trees had been felled for sawtimber prior to 1994, including those needed to construct Phinchho Norling Gomba in 1994. In 1994, five of the village's main houses had been built of timber and stone (the first in 1978), and three additional households were stockpiling timber to build such homes. Four of the existing five were owned by the village's wealthiest households, indicating a strong influence of wealth on timber consumption. A few large trees had also been felled at Chitre by wealthier people of nearby Baysinda Village, where high-quality timber trees are essentially unavailable. According to local informants, construction of a timber-and-stone home requires four to six trees >100 cm

DBH (diameter at breast height). This corresponds with Mahat et al.'s (1987b) estimate of 7-8 medium-sized trees (avg. 36.4 cm DBH) per house in Sindhu and Kabhre Districts of Nepal.

Households travel an average ~550 m (SD ≈ 300, n = 10), or about 25 minutes walking time, to harvest timber. Within ~500 m of village center, the six most preferred timber species (*Acer campbellii*, *Castanopsis hystrix*, *Litsea elongata*, *Michelia kisopa*, *Persea clarkeana*, and *Persea duthiei*, in aggregate) comprise less than 4% of trees >25 cm DBH, whereas beyond ~500 m these species account for 26-36% of trees >25 cm DBH (Fig. 2.14).

Tree fodder

At Chitre, nearly all tree fodder is harvested from wild trees. In 1994, about ten *Ficus* (*F. auriculata* and *F. neriifolia*) were being cultivated for fodder. Tree fodder is harvested by men, women, or children, by climbing as high as 30 m and lopping leafy branches with a machete-like *khukuri* (N.). Harvest occurs primarily in spring but also in winter when necessary (Fig. 2.6). Tree fodder use peaks in early spring, when cropland fodders are exhausted, and is lowest in early summer, when potato fields are being weeded and harvested.

Seventeen tree species are considered average or better for fodder (Table 2.5), with the highest-ranked uncultivated species being, in order of declining preference, *Schefflera impressa, Ficus neriifolia*, *Persea clarkeana, Michelia kisopa*, and *Litsea elongata*. Informants based their rankings on personal observation and local knowledge of selectivity and weight gain by livestock. Elsewhere in the TSENH, tree fodder species vary depending on species composition of local forests, degree to which wild high-ranking tree fodder supplies are over-exploited, and degree to which fodder trees are cultivated.

Tree fodder comprises 13% of the fodder provided to stall-fed livestock at Chitre. The balance (87%) is made up of agricultural residues, primarily corn stalks and cropland weeds.

Household use at Chitre averages 60 *bhAri* (person-loads)/yr (or 1860 kg/yr, assuming Mahat et al.'s 1987b estimate of 31 kg per *bhAri*), and ranges from 0-140 *bhAri* (4340 kg)/yr. Households that own village-based herds (n = 6) use an average of 71 *bhAri* (2201 kg) per year, or ~15.5 *bhAri* (480 kg)/animal/yr (assuming constant herd size and accurate recollections). Use is not correlated with household size, wealth ranking, or land under maize or potato cultivation.

Chitre households travel an average ~475 m (SD ≈ 206, n = 10), or about 10 minutes walking time, to harvest tree fodder for stall-feeding. The abundance of wild, high-ranking, fodder species increases with distance from the village (r_s = 1.0, df = 4, P = <0.01, disregarding *Ficus* trees cultivated for fodder on village croplands), whereas the proportion of lopped fodder trees increases with proximity (r_s = -0.97, df = 5, P = <0.01, Fig. 2.15). Within ~300 m of the village, nearly all fodder trees are *Ficus neriifolia* maintained for fodder production, and 100% have lopped branches. Except for those individual trees, *Ficus neriifolia*, *Persea clarkeana*, *Schefflera impressa* are absent or extremely rare within 500 m of the village center.

Forest litter

Dry leaves (N. *pAtkAr*) are collected from the forest floor during the dry season (November-April) and transported to the village in large bamboo baskets, usually by women or children (Fig. 2.16), where they are deposited in small storage sheds or storage areas within livestock sheds. Every few days, a new layer of leaves is spread on the floor of livestock sheds for bedding, and used bedding - now blended with manure - is added to a mound of curing mulch just outside the shed (Fig. 2.17). In winter, cured mulch is spread judiciously onto croplands and tilled into the soil with an ox-drawn plow (Fig. 2.18).

Leaves of virtually any woody plant species are acceptable for mulching, but preferred species have broad, medium-sized, leaves that are shed over a short period of time, creating a thick layer on the forest floor that can be collected and transported with minimal effort. Species at Chitre having such characteristics include *Lyonia ovalifolia*, *Alnus nepalensis*, and *Prunus* spp.

Chitre households harvest an average ~195 *bhAri* of forest litter per year (SD = 77.5, excluding one household that reported an exceptional 2000 *bhAri*/yr), or ~45 m^3 (average *pAtkAr* basket volume = 0.23 m^3 (SD = 0.05, n = 9)). Household use is positively correlated with wealth ranking (r_s = 0.62, df = 9, P = 0.07), number of full-time residents (r_s = 0.68, df = 9, P = 0.05), and number of village-based livestock (r_s = 0.77, df = 9, P = 0.01), but not with the area of land under maize or potato cultivation.

Households travel an average ~320 m (SD ≈ 144, n = 10), or about 7 minutes walking time, to harvest forest litter. I did not measure forest litter availability in the field, but it is reasonable to assume it is highly correlated with forest cover, which increases more or less linearly with distance from the village. The average household collection location occurs where forest cover is ~55% (Fig. 2.19).

Bamboo

During the autumn "bamboo season" (Fig. 2.6), hundreds of men, women and children from Chitre and nearby Rai Villages harvest bamboo in Chitre Forest. For nearby Rais, Chitre Forest is the nearest source of highly-prized *malingo* bamboo (N., *Yushania maling*). Bamboo culms are cut close to the ground with a single stroke of a *khukuri* (N. machete-like knife). Culms found to be damaged by boring insect larvae are cast aside. 15-20 culms are cut to the same length, bound together in a bundle (N. *bhAri*) and dragged to the village (Fig. 2.20). Most of the bamboo harvested is used to make split-bamboo panels (N, *chitra*; Fig. 2.21), which are then used to build or repair traditional-style dwellings and sheds (Fig. 2.1).

Household bamboo harvest averages ~11.5 *bhAri*, or ~690 culms, per year. Annual per capita consumption (including seasonal residents) ranges from 0.9 to 3.8 *bhAri*, and decreases (marginally) with household size (r_s = -0.66, df = 9, P = 0.06). Consumption varies from year to year depending on the number of construction or repair projects undertaken. Traditional bamboo houses and sheds require major repairs every 5-7 yrs (Sundriyal and Sharma 1996).

Households travel an average 1300 m (SD ≈ 415, n = 10), or ~60 minutes walking time, to harvest malingo bamboo. Within 300 m of village center, nearly all bamboo is smaller species that are not useful for making *chitra*. Availability of malingo bamboo increases steadily beyond 300 m (Fig. 2.22). Local informants report it was formerly available closer to the village but the colonies were extirpated by overgrazing of young shoots.

Pollarded stems

Pollarding is a pruning system in which the branches of a tree or shrub are removed in order to promote the growth of a cluster of elongated stems. Pollarded stems (N. *gotcha*) are used to make lightweight livestock barriers and rafters for thatched roofs. There are no preferred species *per se*, but some species tolerate repeated pollarding more than others, such as *Symplocos* spp.*, Lyonia ovalifolia, Eurya acuminata* and *Viburnum erubescens* (also see Cowan 1929). Stems of *Viburnum erubescens* are sometime planted to create living fences (Fig. 2.23).

I did not attempt to assess household consumption of pollarded stems. As with bamboo, household consumption varies from year to year. Stems are needed to extend or fortify livestock barriers whenever new fields are put into production or cropping or grazing patterns are altered, and every 5-7 yrs to repair bamboo dwellings and sheds. Each autumn, prior to the arrival of itinerant livestock herds, minor fence repairs are also needed.

Most stems are collected within ~200 m of households, or <5 minutes walking time. Within ~300 m of the village, ~60% of all sampled trees 10-25 cm DBH had pruned branches

(Fig. 2.24). Beyond ~300 m, the proportion with pruned branches declined precipitously to <10%.

Discussion

Residents of Chitre have distinct preferences for woody plant resources. Preferred types are frequently not the most used because less preferred types are available closer to the village. Household size, wealth, and number of livestock sometimes influence household choices regarding harvest and consumption of some forest resources. With the exception of malingo bamboo, woody plant species that regenerate more quickly in relation to their rate of harvest remain available closer to the village.

Fuelwood

Average per capita fuelwood consumption at Chitre, ~3.8 m^3/yr, is high by both regional and international standards (Hall et al. 1982). The average consumption rate for Nepal is ~1.0 m^3/person/yr (Thompson and Warburton 1985), and for the Mamlay watershed of southern Sikkim it is 1.5-2.1 m^3/person/yr (Sundriyal and Sharma 1996). Consumption rates are generally higher at higher elevations, where access to forests is good, and where human populations have historically been low (Bajracharya 1983, Fox 1984, Mahat et al. 1987b). Chitre's relatively high fuelwood consumption is mostly a consequence of elevation (2350 m), proximity to natural forest, energy-inefficient cooking hearths, and Sherpa social customs. Home-brewed alcoholic beverages (S. *chang*, N. *rakshi*) are central to Sherpa hospitality (Fürer-Haimendorf 1964), and each batch requires 20-25 kg of fuelwood to brew. Among other Sherpa communities fuelwood use ranges widely, depending on availability (Sherpa 1979, Stevens 1993).

At Chitre, the decline in per capita fuelwood consumption with increasing household size is probably the result of a fuelwood 'economy of scale,' whereby per meal fuelwood requirements decrease with each additional meal cooked (Fox 1983, Metz 1989a). In contrast to Metz's (1989a) findings at Chimkhola, a 270-household, mixed-culture village in west-central Nepal, per capita fuelwood consumption at Chitre is not correlated with household labor resources or land holdings, perhaps because of Chitre's comparatively small size and uniform socioeconomic composition.

At Chitre, 72% of cooking fires were made from felled firewood, and just 7% from *jhikra* (cropland residues). Elsewhere in eastern Nepal, Bajracharya (1983) found household fuel to consist of 31% felled fuelwood and 14% *jhikra*, and 50 km east of Kathmandu, Mahat et al. (1987b) found *jhikra* to comprise 51% of household fuel. In the Khumbu Region, where residents are relatively wealthy, *jhikra* is seldom used, even though fuelwood is difficult and expensive to acquire (Stevens 1989).

According to Chitre residents, preferred fuelwoods are easier to ignite, produce more heat, combust longer, and leave less ash (Table 2.2). The proportionately low use of first-ranked species (*Myrsine semiserrata*, *Quercus lamellosa*, *Quercus oxyodon*, and *Vibernum erubescens*), suggests households trade off fuelwood quality for the lower harvest, transport, and processing costs of lower-ranked species (especially *Alnus nepalensis*, *Lyonia ovalifolia*, and *Rhododendron arboreum*). First-ranked species require more effort to access, cut, and split. Households with more full-time residents and greater wealth can bare the higher labor costs of high-ranked fuelwoods, whereas smaller, poorer, households cannot.

The low availability of high-ranking fuelwood species within 300 m of the village is presumably the result of unsustainable harvest rates in the past. High-ranking fuelwood species regenerate poorly in this zone due to over harvest and intense grazing pressure, but average-ranked species, which provide most of Chitre's fuelwood, are relatively abundant (Fig 2.12).

High-ranked fuelwood species tend to be slow-growing late-successional species, whereas average-ranked species tend to be fast-growing pioneer species (see Chapter 3) and less palatable (Table 2.5). Average-ranked species are least available at 300-500 m distance, just beyond where most felled fuelwood is currently harvested (average distance = 284 m). They are not as available <300 m from the village as basal area measurements suggest (Figure 2.12), because there are many young trees in this zone that are too small to harvest for fuelwood. The increasing basal area of average-ranked species beyond the current fuelwood harvest zone reflects the growth of pioneer species to medium and large size in areas where the forest canopy has been thinned.

The impacts of fuelwood and timber harvest on forest structure and composition are similar. Falling and removing individual canopy trees creates gaps in the forest canopy similar to gaps created by trees that fall naturally (Blake and Hoppes 1986, Levey 1988). If limited and dispersed, green-falling trees for fuelwood or timber can be seen as replicating natural ecological processes (although harvest removes nutrients from the forest ecosystem). Over the long term however, if high-ranked species are felled faster than they are replaced through recruitment, they become replaced by faster-growing, disturbance-tolerant, sub-canopy species, thereby transforming the forest (Sundriyal and Sharma 1996, Metz 1998). Selective harvest of size classes distorts the natural age distribution of stands (Sundriyal and Sharma 1996), compromising future regenerative capacity (Oliver and Larson 1990).

The ecological impact of fuelwood harvest can be reduced by designating areas near the village for cultivating second-ranked, fast-growing, fuelwood species. Grazing would have to be excluded or well regulated at these sites. It can also be reduced by introducing new practices or technologies to reduce fuelwood consumption, or make it more energy-efficient. Traditional *chulli* hearths can be replaced with more efficient, less harmful, semi-enclosed stoves (N. *chulo*), which have been adopted throughout the developing world where fuelwood supplies are limited. But Chitre residents have been reluctant to forsake their convivial but unhealthy and inefficient *chulli* because fuelwood remains plentiful. They also dislike the *chulo* because it can heat only two or three pots at a time.

Electrical power will someday alter Chitre's reliance on fuelwood as a household energy source. The Nepalese government has proposed building a hydroelectric generating plant on the nearby Sisuwa River to provide electricity at a subsidized installation cost of NR 448238 (~$4465) per household (C. Sherpa, *pers. comm.*), a very high price for poor farmers. A village-based photovoltaic system would also be very expensive for village residents to finance and maintain, and not effective during the monsoon season. When electricity does arrive at Chitre, experience elsewhere suggests it will be used primarily for illumination and for powering small consumer appliances (e.g., radios, televisions), not for cooking or heating (IEA 2006). Where fuelwood remains readily available, as it does at Chitre, the primary benefits of electrification are improved health and a higher standard of living (IARC 2010). Overall consumption of fuelwood can actually increase with illumination because the daily period of indoor activity is extended into dawn and dusk, in turn increasing the consumption of fuelwood for heating purposes.

Timber

Timber consumption will increase as Chitre households become increasingly wealthy, because wealthier households prefer homes built of timber-and-stone. The ecological impacts of timber harvest can be reduced by planting and safeguarding seedlings of timber species in secondary forest. Grazing would need to be well regulated at these sites because many timber species are palatable to livestock (*Michelia kisopa, Persea* spp., *Quercus* spp., Table 2.5). Community-regulated grazing schemes have started to be implemented throughout the Makalu

Barun Buffer Zone (Matha and Kellert 1998).

Greater use of alternate timber species should be encouraged to reduce harvest pressure on *Michelia kisopa,* the current favorite. Elsewhere in Nepal, a range of species is used for different construction applications (Mahat et al. 1987b, Metz 1989a), but Chitre residents seldom use *Prunus* or *Acer* spp., which are prized for woodworking elsewhere.

Tree Fodder

Across the region, household tree fodder use varies with climate, degree of forest degradation, area of cropland in production, and amount of cultivated fodder available. Average household tree fodder consumption at Chitre, 60 *bhAri*/yr*,* is much lower than the 115 *bhAri*/yr (Mahat et al. 1987b) or 142.4 *bhAri*/yr (Metz 1989a) reported for west-central Nepal, primarily because fewer livestock are kept per household at Chitre (10.5 and 9.6, versus 4.6 at Chitre). Metz reported similar per animal consumption rates (14.9 *bhAri*/yr versus 15.5 *bhAri*/yr at Chitre), but a much higher proportion of tree fodder (48% of all fodder versus 13% at Chitre). Mahat et al. reported lower per animal consumption (11 *bhAri*/yr), and a somewhat higher proportion of tree fodder (20.5%). In southern Sikkim, where households kept an average of only four animals (Sundriyal and Sharma 1996), household "forest fodder" consumption averaged 232 *bhAri*/yr (assuming 31 kg/*bhAri*, Mahat et al. 1987b), which also included significant amounts of "floor biomass" (plant material from the forest floor).

Preferences for tree fodder species at Chitre are partly corroborated by laboratory tests by Bajracharya et al. (1985), who report that three of the highest-ranked species (*Ficus neriifolia*, *Michelia kisopa, Schefflera impressa*) have high crude protein content relative to other Nepalese fodder species (9.9-12.8%). Elsewhere in the Himalaya, *Quercus* species are often reported to be the primary tree fodder species (Shakya 1975, Fox 1983, Pandey and Singh 1984, Singh et al.

1984, Moench and Bandyopadhyay 1986, Metz 1989a, Schmidt-Vogt 1990). Perhaps *Quercus* species are considered second-ranked at Chitre because *Quercus lamellosa*, the predominant oak species, has lower crude protein content than at least five other available tree fodder species (Table 2.5).

The inverse relationship of fodder tree abundance and fodder tree lopping (Fig. 2.15) strongly suggests lopping is a key cause of decreased fodder tree abundance closer to the village. Fodder lopping has frequently been implicated as the principal cause in the decline, or “nibbling away” (Moench and Bandyopadhyay 1986), of broadleaved forests around villages throughout the Himalaya (Stainton 1972, Shakya 1975, Metz 1987, Saxena and Singh 1984, Upreti et al. 1985).

Heavy lopping drastically reduces the canopy volume of trees, transforming them into ragged poles. Photosynthetic activity and nutrient uptake are reduced, fungal infections increase (Metz 1987, Metz 1989b, Shrestha 1989), and death comes prematurely. After dying they are felled for fuelwood. Under typical lopping and grazing regimes, fodder trees have difficulty regenerating (Metz 1987, 1990, 1994), and eventually become replaced by less palatable, disturbance-resistant, species (Sundriyal and Sharma 1996).

The ecological impacts of tree fodder harvest can be reduced by feeding more fodder grown on croplands (e.g., alfalfa or clover). However, croplands are sometimes barely sufficient to produce staple food crops (due to rugged terrain), and farmers are unable or unwilling to trade off food production for fodder production. Gilmour (1988) reports farmers in midland Nepal have responded to declining sources of wild tree fodder by cultivating fodder trees on private land, at the perimeter of cultivated fields, as three Chitre households have done. Introduction of improved livestock breeds would also reduce the overall size and environmental impact of livestock herds.

The impact of tree fodder harvest can also be reduced by planting and safeguarding fodder tree seedlings in designated tree fodder production areas in secondary forest. Grazing would need to be regulated at these sites, perhaps by a system of rotational grazing, whereby livestock would graze in a series of delineated areas, allowing sufficient time between grazing events for tree seedlings to become sufficiently robust to withstand light browsing. Perhaps recently implemented community-regulated grazing schemes (Matha and Kellert 1998) will someday incorporate such measures.

Other Forest Resources

Consumption of forest litter is higher among Chitre households that own more livestock, presumably because they have more manure available to produce mulch. Higher litter consumption by larger and wealthier households reflects the greater labor and financial resources available to commit to mulch production, which ultimately increases crop yields.

An average household harvest distance of ~320 m indicates forest litter is generally not available in shrubby pastures or secondary forest near the village. Many woody species that occur close to the village are not desirable for mulching because they have small, narrow, and sometimes spiny leaves. As forest cover recedes due to the “nibble effect,” access to forest litter becomes increasingly difficult. Availability of leaf litter can be increased near the village by conserving or reestablishing dense canopies of desirable tree species near the village.

Over the long term, collection of forest litter deprives forest soils of nutrients, decreases rainfall infiltration, and exposes soils to erosion (Oli and Manandher 2002). The ecological impact of forest litter harvest can be reduced by adopting commercial or chemical fertilizers, but their use is generally not economically feasible in remote areas where farming is done primarily for subsistence.

Estimates of bamboo and stem consumption are not available from elsewhere for comparison. Among all major forest resources, Chitre residents harvest malingo bamboo at the furthest distance ($\bar{x}$ = 1300 m), and stems most nearby ($\bar{x}$ <200 m). Malingo bamboo is more heavily utilized by residents of other nearby villages than any other woody plant resource.

The impacts of bamboo and stem harvest can be reduced by using more durable building materials, such as stone, metal, and lumber, but many poor residents lack the economic resources and construction skills to use these materials. Extirpated bamboo colonies can be reestablished by seeding or transplanting, but technical assistance might be needed to determine optimal restoration sites, and livestock grazing would need to be closely regulated in those areas.

TABLE 2.1. Household composition at Chitre Village.

Wealth rank[A]	Total adults[B]	Resident adults	Total children	Resident children	Total land (ha)[C]	Potato fields (ha)[F]	Water buffalo	Cattle	*Chau˜ri*	Goats	Pigs
1	4	3	3	3	3.19[D]	1.00	3	6	0	0	0
2	6	4	1	0	5.49	0.92	0	1	29	0	1
3	4	4	2	2	2.53	0.96	5	0	0	0	1
4	4	2	4	3	3.80[E]	0.83	0	0	30	0	1
5	2	2	0	0	0.96	0.77	4	0	0	0	0
6	2	1	1	1	2.62	0.70	0	16	1[G]	2	1
7	2	2	7	6	3.28	0.76	2	4	0	0	0
8	2	2	6	6	1.47	0.90	1	7	0	0	0
9	1	1	4	2	2.38	0.58	0	1	0	0	1
9	2	1	1	1	2.01	0.73	0	0	0	0	0
Total	29	22	29	24	26.74	7.63	15	35	60	2	5
Average	2.9	2.2	2.9	2.3	2.67	0.76	1.5	3.5	6	0.2	0.5
SD	1.5	1.1	2.3	2.3	1.42	0.19	1.9	5.1	12	0.6	0.5

[A]Mean rank according to opinion of four informants that represented the range of household wealth. Wealth rankings of the two wealthiest households were tied. [B]Adults ≥ 18 years of age. [C]Sum holdings of all household residents (source: Government of Nepal, 1994 cadastral survey). [D]Household also owned irrigated fields in nearby village. [E]Household also owned subalpine pastures. [F]Estimated area planted in potatoes in 1994. [G]A yak.

TABLE 2.2. Quality rankings for woody plant species used as fuelwood.[A] Dashes indicate information is lacking.

Species	Overall ranking	Ease of ignition	Heat production	Combustion duration	Ash production	Drying speed	Index value[B]
Acer campbellii	average	--	--	--	--	--	--
Alnus nepalensis	average	good	--	short	high	fast	1636
Castanopsis hystrix	average	average	--	long	low	slow	--
Eurya acuminata	average	good	hot	long	average	slow	--
Ficus neriifolia	average	--	--	--	--	--	--
Hydrangea heteromalla	not good	--	--	--	--	--	--
Ilex sikkimensis	average	--	--	--	--	--	--
Lindera assamica	average	--	--	--	--	--	--
Lindera pulcherrima	average	--	--	--	--	--	--
Litsea elongata	average	--	--	--	--	--	600
Lyonia ovalifolia	average	good	--	average	average	slow	--
Magnolia campbellii	not good	--	not hot	--	--	--	--
Meliosma pinnata	not good	--	--	--	--	--	--
Michelia kisopa	average	--	--	--	--	--	--
Myrsine semiserrata	good	--	hot	--	--	--	--
Persea clarkeana	average	average	--	average	average	slow	--
Persea duthiei	average	average	--	average	average	slow	--

TABLE 2.2. Continued.

Species	Overall ranking	Ease of ignition	Heat production	Combustion duration	Ash production	Drying speed	Index value[B]
Prunus spp.	average	--	--	--	--	--	--
Quercus lamellosa	good	average	hot	long	average	slow	--
Quercus oxyodon	good	average	hot	long	average	slow	--
Rhododendron arboreum	average	good	--	average	average	slow	2399
Schefflera impressa	average	--	--	--	--	--	--
Symplocos ramosissima	not good	average	not hot	short	average	slow	890
Symplocos theifolia	not good	average	not hot	short	average	slow	--
Tetradium fraxinifolia	not good	--	--	--	--	--	--
Vibernum erubescens	good	good	hot	long	average	slow	1655

[A]Ranked by a group of five male heads of households.

[B] Fuelwood Index Value (Purohit and Nautiyal 1987, Bhatt and Todaria 1992), (Calorific value x density)/(ash content x water content).

TABLE 2.3. Weight and volume loss by three fuelwood species after drying over an open hearth.[A]

	Green-cut weight (kg)	Hearth-dried weight (kg)	% weight loss	Hearth-dried volume (m^3)[B]	Hearth-dried kg/m^3
Rhododendron arboreum	10.0	6.5	35	0.007	929
Alnus nepalensis	14.0	5.0	64	0.01	500
Lyonia ovalifolia	12.0	4.0	66	0.01	400
Average	12.0	5.17	55	0.009	610[C]

[A]Dried on a rack over an indoor cooking hearth for 32 days. [B]Volume determined by displacement of water. [C]Closely matches the 600 kg/m^3 value assumed by Fox (1984).

TABLE 2.4. Household fuelwood consumption at Chitre Village.

Wealth rank[A]	Full time residents	Mean daily use (kg)[B]	Annual use (kg)[B]	Annual per capita use (kg)[B]	Distance to harvest (m)
1	6	46.8	17,082	2,847	450
2	4	30.6	11,169	2,792	450
3	6	39.2	14,308	2,385	245
4	5	30.5	11,133	2,227	125
5[C]	2	25.1	9,162	4,581	415
6[D]	2	50.5	18,433	9,217	425
7	8	21.9	7,994	999	100
8	8	30.5	11,133	1,392	375
9	3	30.9	11,279	3,760	150
9	2	20.9	7,629	3,815	100
Average	4.9	33.5	12,240	3,270	284
SD	2.3	10.2	3,706	2,420	154

[A]Mean rank according to opinion of 4 informants representing the range of household wealth. Wealth rankings of the two wealthiest households were tied. [B]Standardized to air-dry moisture content. [C]The PI and staff ate meals at this household along with the residents, so it was omitted from most fuelwood consumption analyses. [D]This household used greater proportions of fast-burning, medium-ranked *Alnus nepalensis* than other households (65% versus <55%).

TABLE 2.5. Quality rankings of woody plant species used for tree fodder.[A] Dashes indicate crude protein estimates are unavailable.

Species	Overall fodder ranking	Percent crude protein[B]
Acer campbellii	average	--
Alnus nepalensis	poor	24.3
Castanopsis hystrix	poor	8.3
Eurya acuminata	average	8.5
Ficus neriifolia	good	12.8
Hydrangea heteromalla	poor	--
Ilex sikkimensis	average	--
Lindera assamica	average	--
Lindera pulcherrima	average	--
Litsea elongata	good	--
Lyonia ovalifolia	poor	--
Magnolia campbellii	average	--
Meliosma pinnata	average	--
Michelia kisopa	good	9.9
Myrsine semiserrata	average	5.8
Persea clarkeana	good	--
Persea duthiei	good	8.8
Prunus spp.	poor	--
Quercus lamellosa	average	7.5
Quercus oxyodon	average	--
Rhododendron arboreum	poor	--
Schefflera impressa	good	10.4
Symplocos spp.	poor	--
Tetradium fraxinifolia	average	--
Vibernum erubescens	poor	--

[A]Ranked by a group of five male heads of households. [B]Bajracharya et al. (1985).

FIGURE 2.1. Traditional house and livestock shed constructed of rough-hewn pole timbers (*Symplocus* spp. or *Eurya* spp.), malingo bamboo (*Yushania maling*), pollarded stems, and cow dung plaster.

FIGURE 2.2. Modern timber-and-stone home built primarily of *Michelia kisopa* timber, *Castanpsis hystrix* roof shakes, and locally-quarried stone.

FIGURE 2.3 Chitre Village, comprised of 10 households, with Phinchho Norling Gomba located near the center.

FIGURE 2.4. Phinchho Norling Gomba, built in 1994 with financial assistance from the Makalu-Barun Project.

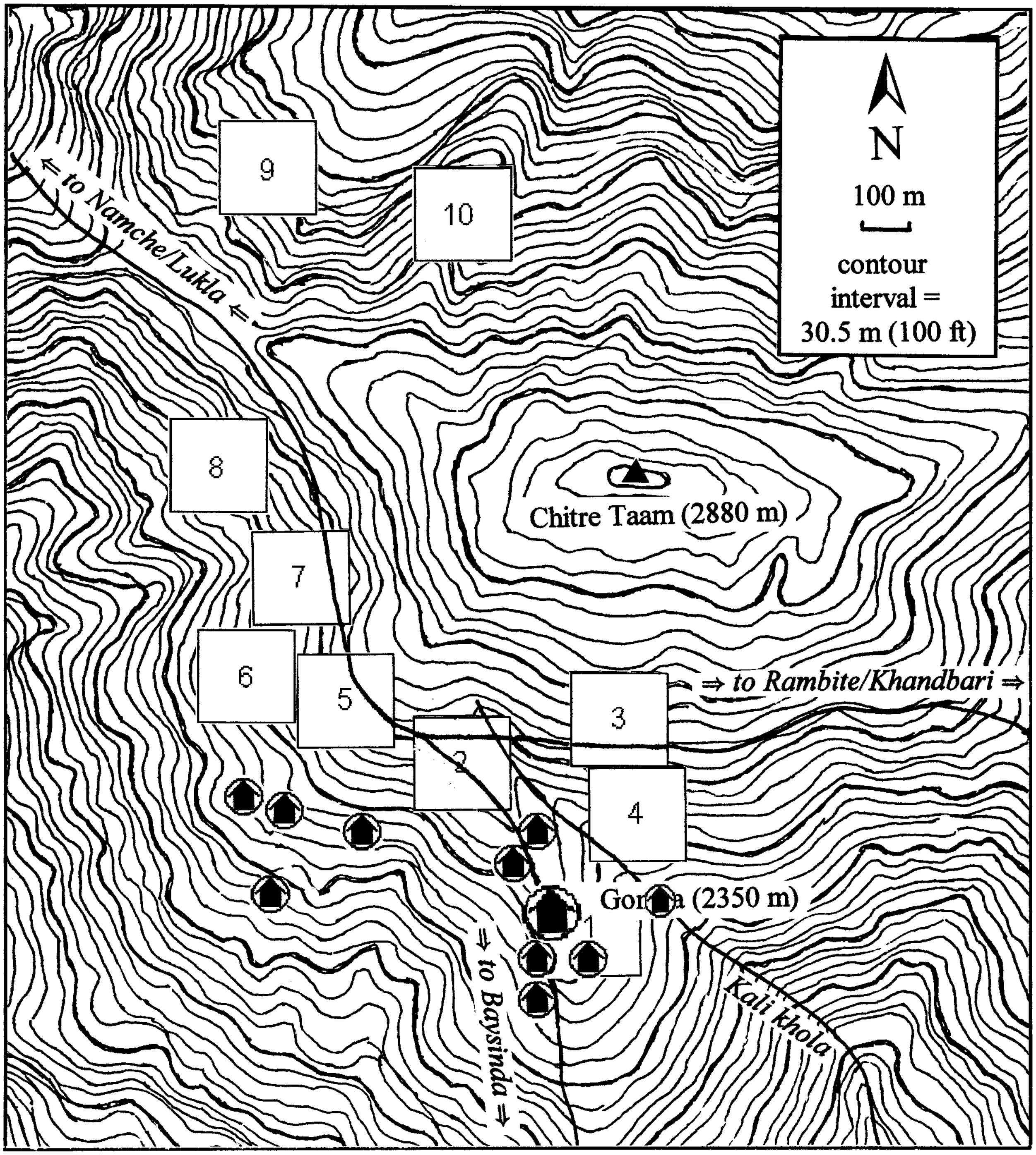

FIGURE 2.5. Locations of study plots and dwellings at Chitre Village. White squares are 9 ha study plots: 1, Chitre Bari; 2, Chitre Kharka; 3, Upper Chaite; 4, Lower Chaite; 5, Hile; 6, Alu Bari; 7, Bagalekhop; 8, Tauke; 9, Chakedho; 10, Bhelli. Small house icons are households, large house icon is Phinchho Norling Gomba.

English month:		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nepali month:		*MAgh*	*PhAgun*	*Chait*	*BaisAkh*	*Jeth*	*AsAr*	*SAun*	*Bhadau*	*Asoj*	*KArtik*	*Mangsir*	*Pus*
Cropland	Potato	plowing	planting		weeding		harvest						plowing
	Maize	plowing	planting		weeding						harvest		plowing
	Taro	plowing	planting		weeding						harvest		plowing
	Barley				harvest						planting		
	Wheat						harvest				planting		
Forest	Fuelwood	dead and down		green-felling					dead and down				
	Timber										felling & ripping		
	Bamboo	as needed									primary season		
	Tree fodder	as needed		primary season								as needed	
	Forest litter	as needed		primary season							as needed		
	Pollarding			spring herding							autumn herding		

FIGURE 2.6. Calendar of crop production and forest use at Chitre Village.

FIGURE 2.7. Children collecting “gathered” fuelwood from shrubby pastures near the village.

FIGURE 2.8. Fuelwood cut from a single large *Quercus* tree, split and stacked to dry. The crown of the tree (center left) was left discarded because its forking branches were considered too difficult to split.

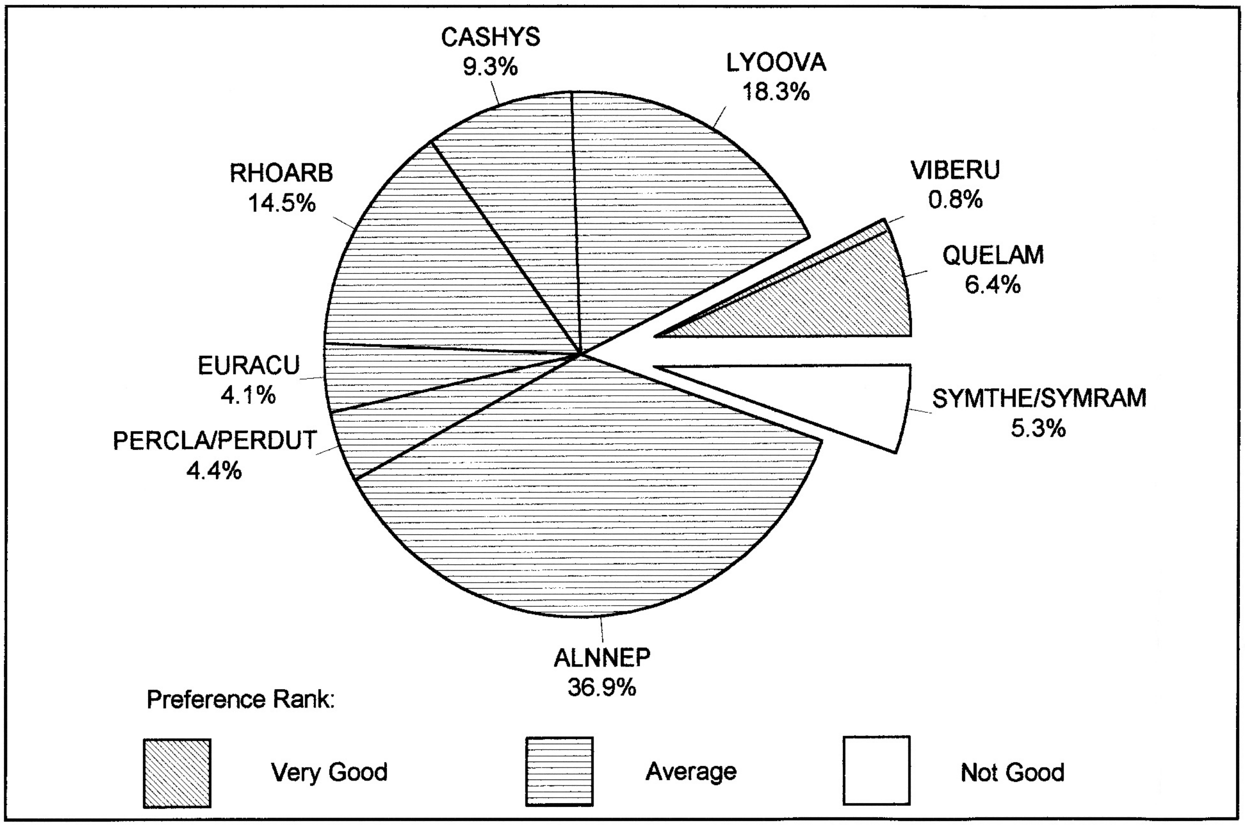

FIGURE 2.9. Proportions of high-, medium-, and low-ranked fuelwood species used at Chitre Village

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FIGURE 2.10. Woman cooking with a traditional Nepalese open hearth, or *chulli*.

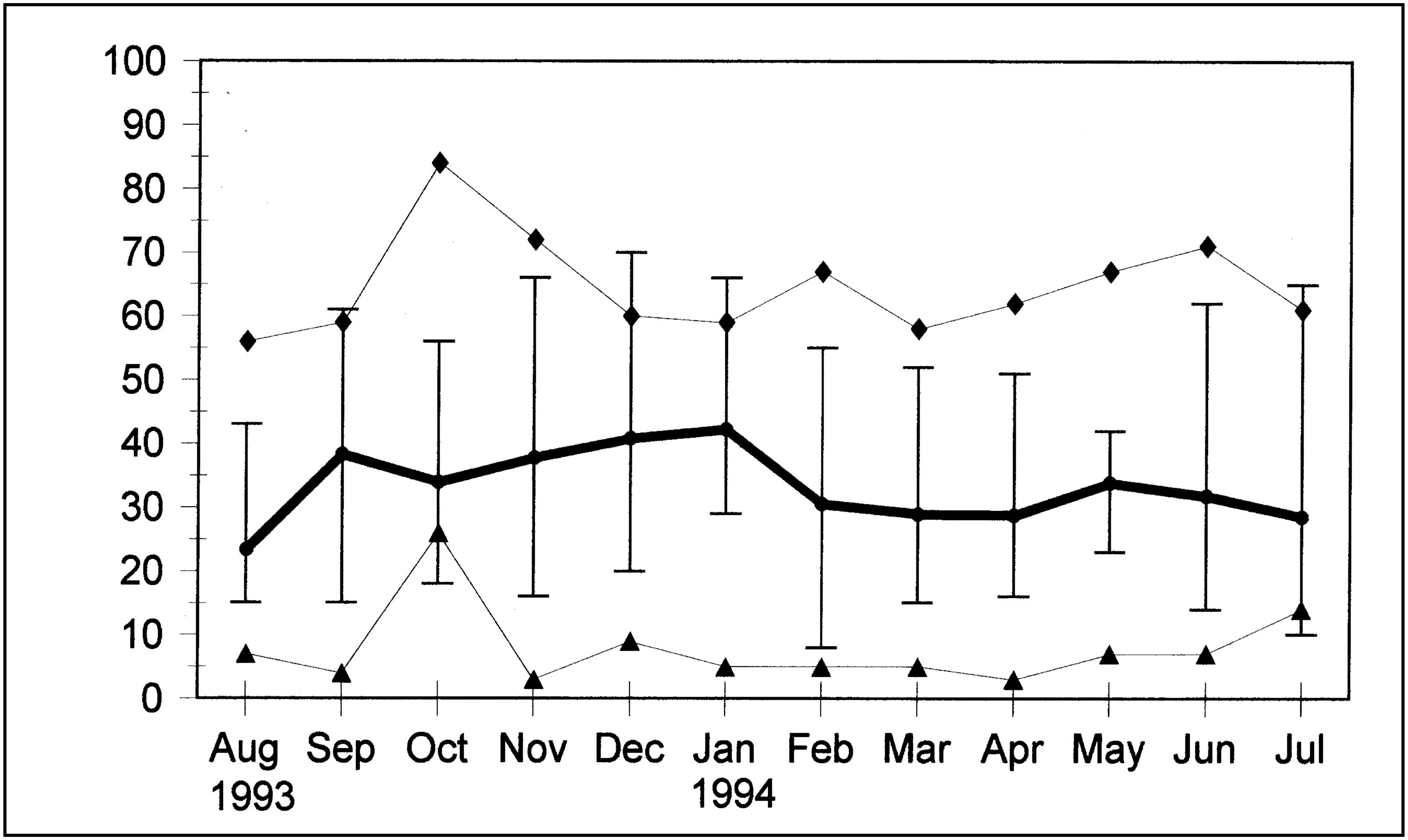

FIGURE 2.11. Household occupancy and fuelwood use by month. Bold solid line is average fuelwood use (kg/d); diamond-studded line, total occupants on sample day (x10); triangle-studded line, guests (workers) on sample day (x10).

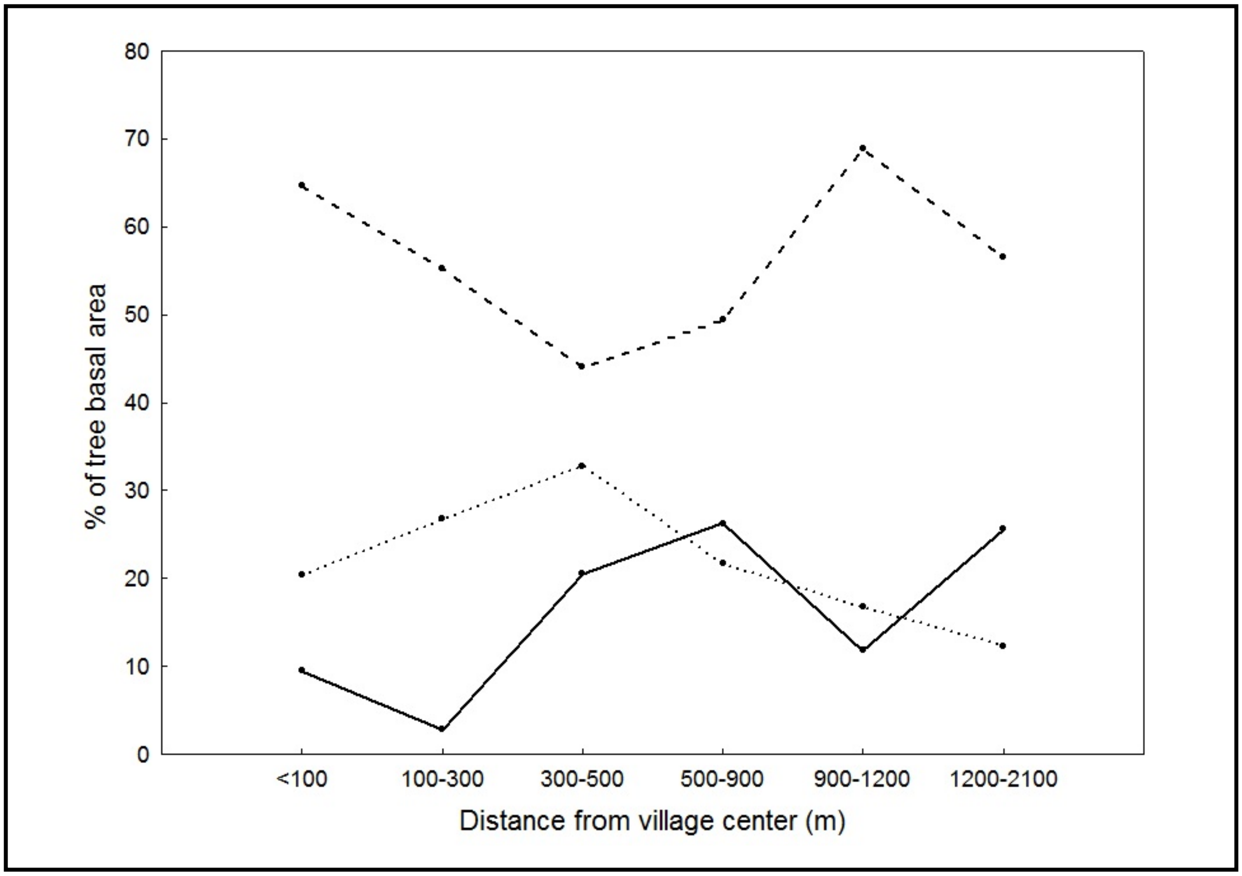

FIGURE 2.12. Availability of high-, average-, and low-ranked fuelwoods at increasing distances from village center. Solid line is the aggregate basal area of high-ranked species (n = 4); dashed line, aggregate basal area of average-ranked species (n = 15); dotted line, aggregate basal area of low-ranked species (n = 6). Horizontal axis is not to scale. Average household harvest site for felled fuelwood is 284 m from village center.

FIGURE 2.13. Rai lumbermen ripping a large *Castanopsis hystrix*.

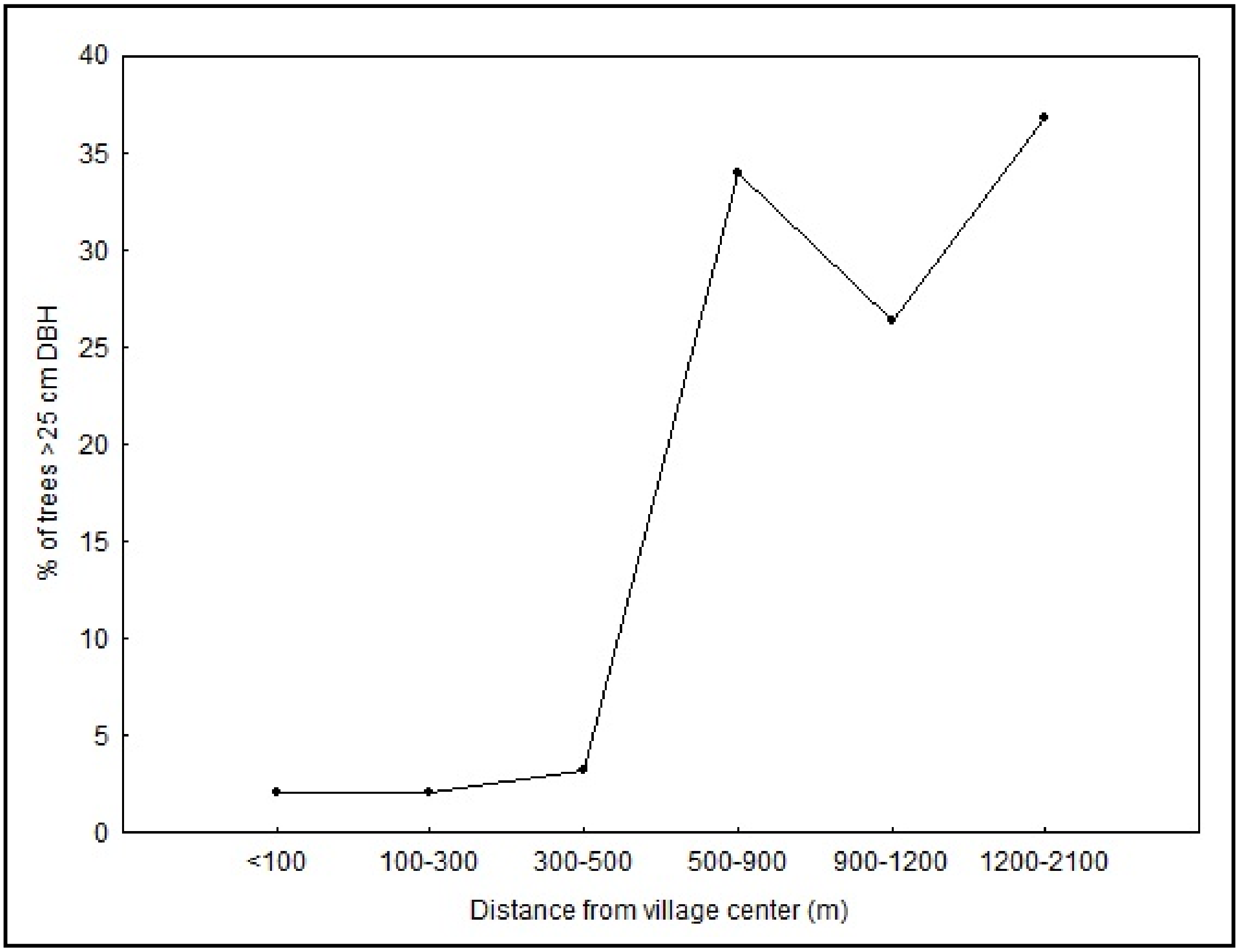

FIGURE 2.14. Availability of six tree species (in aggregate) most preferred for sawtimber at increasing distances from village center. Horizontal axis is not to scale. Average household harvest site for sawtimber is 550 m from village center.

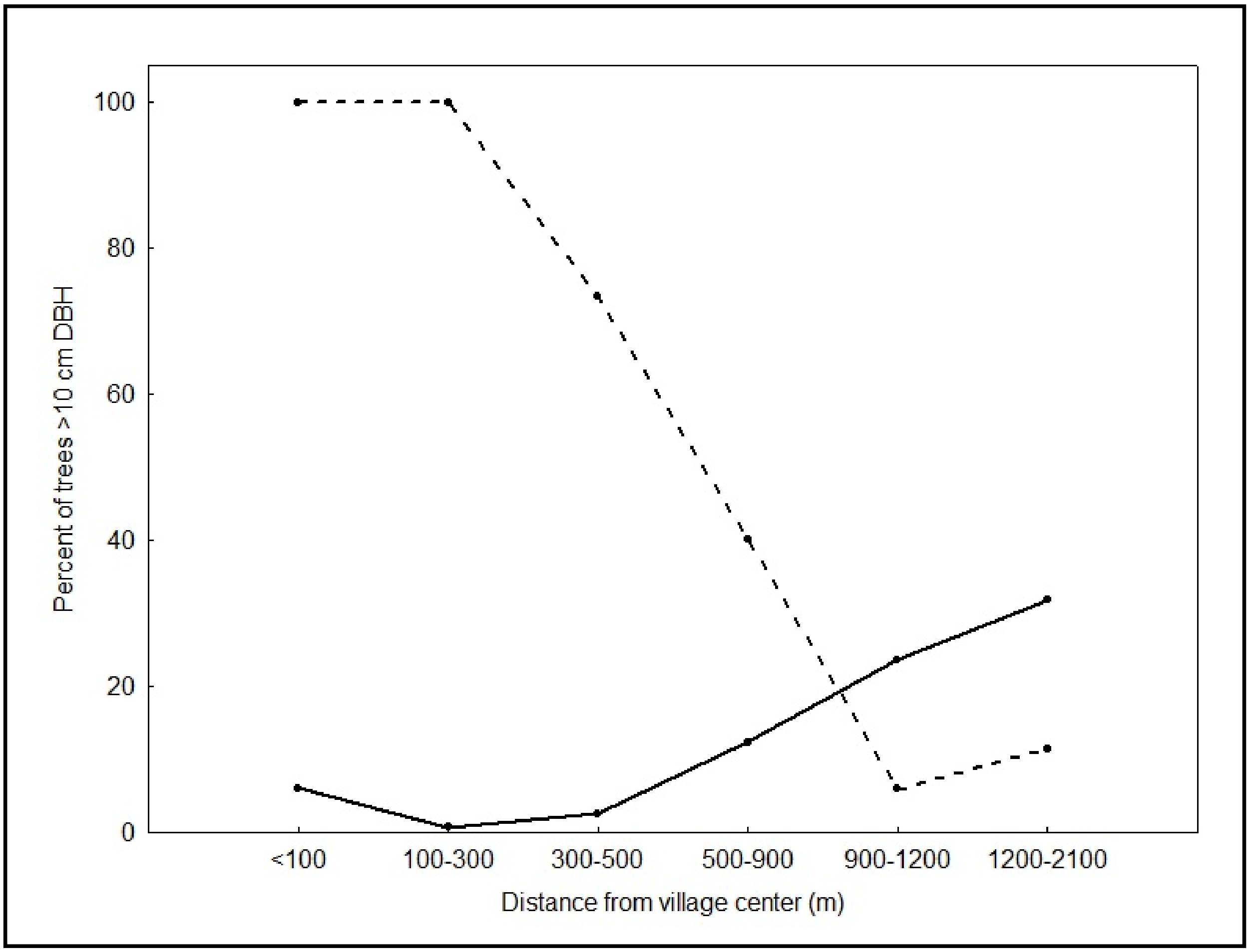

FIGURE 2.15. Availability of tree fodder species >10 cm DBH at increasing distances from village center. Solid line is % frequency of the five highest-ranking tree fodder species in aggregate; dashed line, % of fodder trees with lopped branches. Horizontal axis is not to scale. Average household harvest site for tree fodder is 475 m from village center.

FIGURE 2.16. Women and children collect leaf litter, or *patkar*, from the forest floor and transport it to the village in large bamboo baskets. Two individuals in foreground are Rai laborers.

FIGURE 2.17. Woman adding fouled livestock bedding (leaf litter) to a mulch heap.

FIGURE 2.18. Rai laborer tilling mulch into a terraced field with an ox-drawn plow.

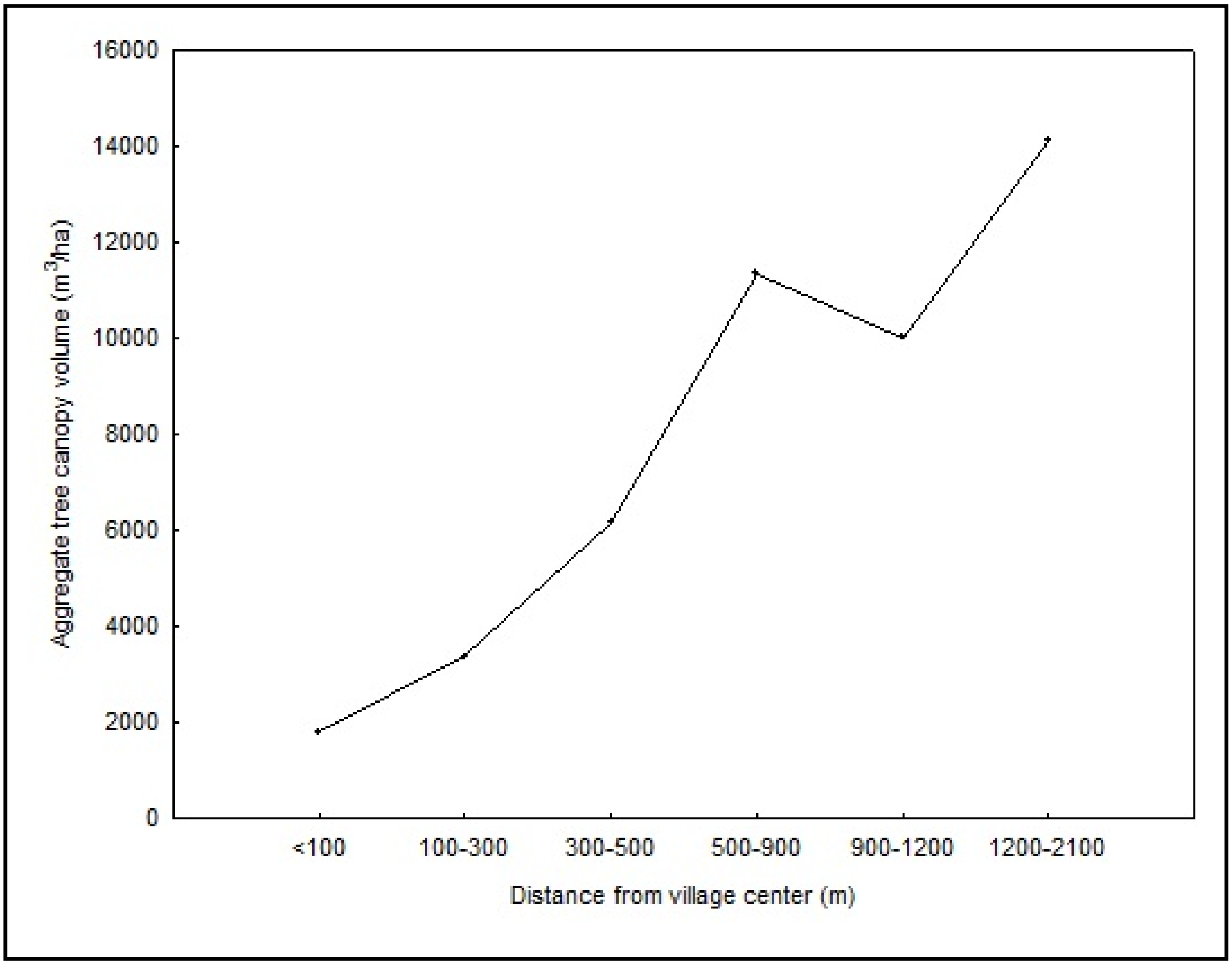

FIGURE 2.19. Aggregate canopy volume of trees >2 cm diameter at base at increasing distances from village center. Horizontal axis is not to scale. Average household harvest site for forest litter is 320 m from village center.

FIGURE 2.20. Rai men hauling *bhAri*s (person-loads) of malingo bamboo harvested ~1 km beyond Chitre Village.

FIGURE 2.21. Woman weaving a *chitra* panel from split malingo bamboo, which will be used to construct or repair the wall or roof of a traditional home or livestock shed.

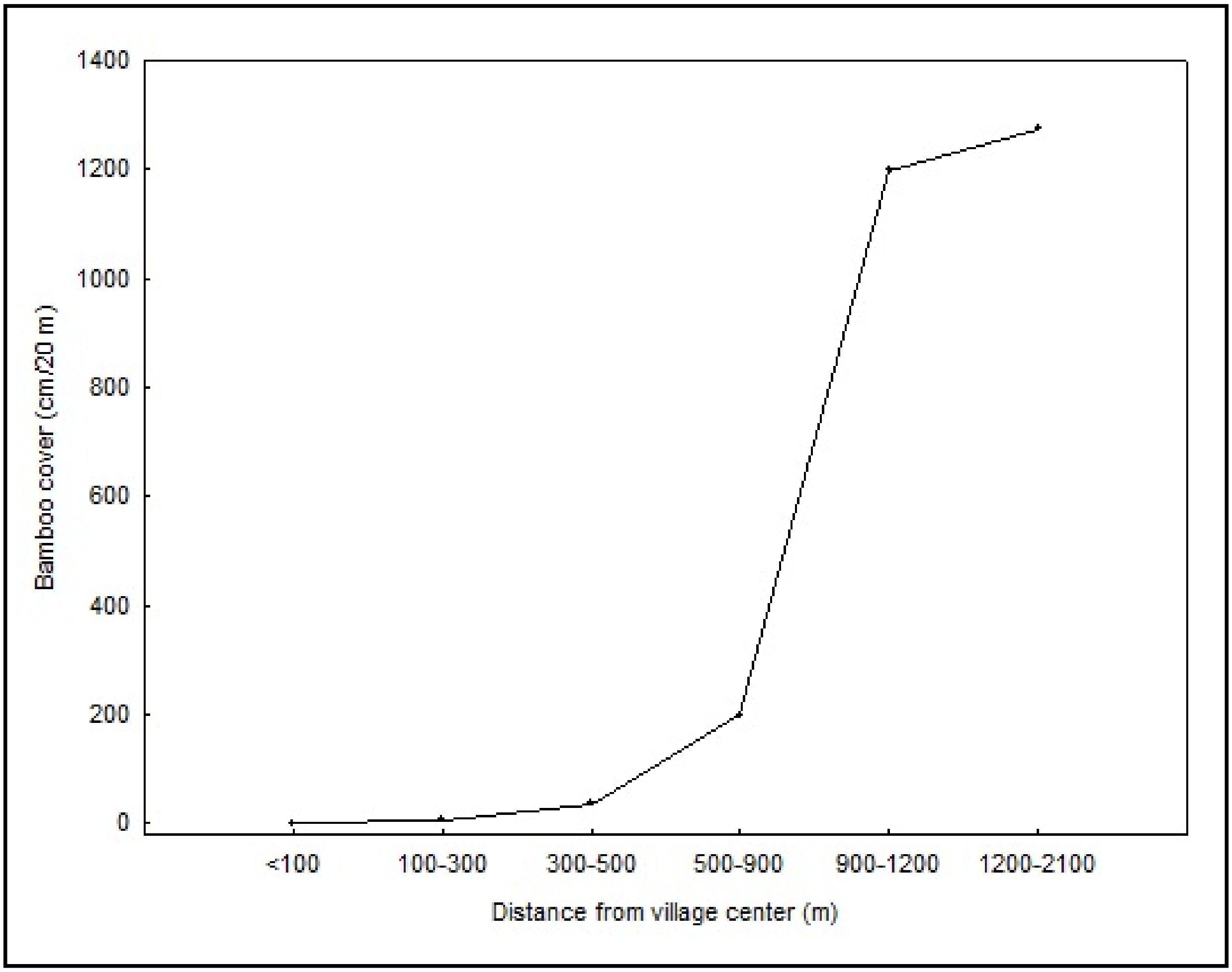

FIGURE 2.22. Availability of malingo bamboo at increasing distances from village center. Horizontal axis is not to scale. Average household harvest site for malingo bamboo is 1300 m from village center.

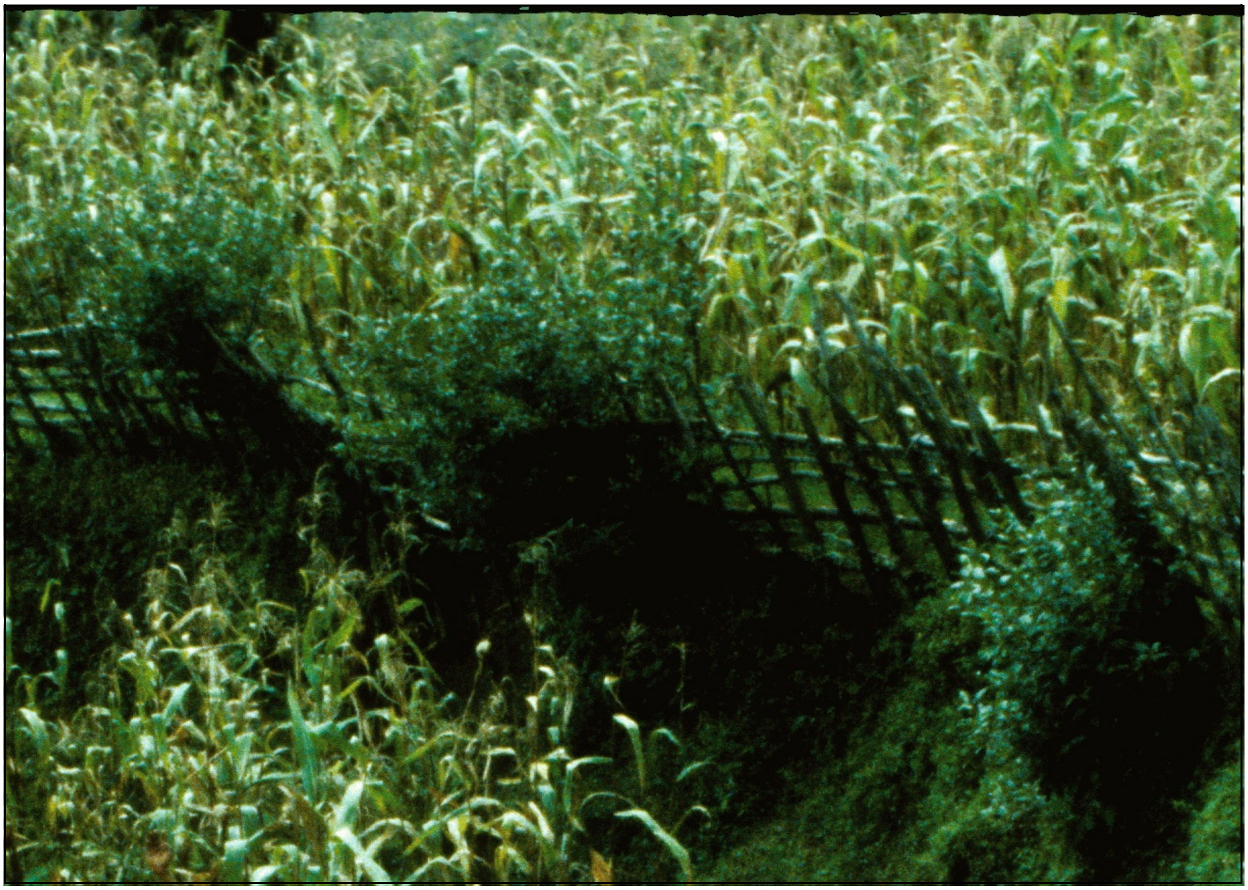

FIGURE 2.23. Living fence created by planting stems of *Viburnum erubescens*.

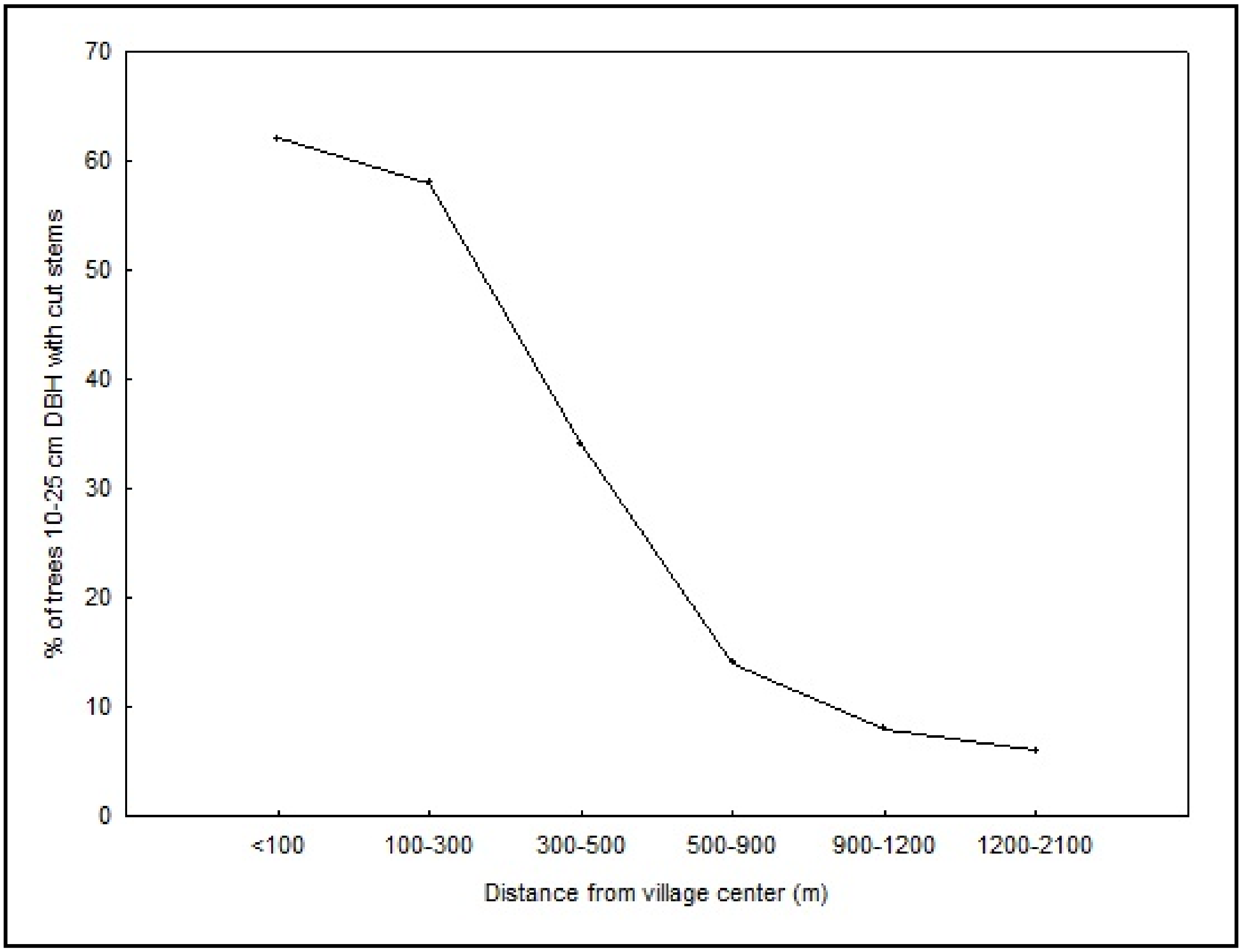

FIGURE 2.24. Percent of trees with cut stems at increasing distances from village center. Horizontal axis is not to scale. Most pollarded stems are collected within 200 m of village center.