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Forest Grazing and Natural Regeneration in a Late Successional Broadleaved Community Forest in Bhutan

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*This study investigated the sustainability of combining forest grazing and timber harvesting with selection felling in a cool broadleaved community forest (CF) in Bhutan. Forest grazing and timber production are critical livelihood activities for many farmers throughout the world, so it is important to understand under what conditions the 2 activities can be combined. The study was based on a household survey to quantify livestock holdings and grazing patterns, a comparison of 2 forest inventories to assess forest structure and regeneration, and a study of stumps to quantify harvesting intensities. During a 5-year period the number of cattle grazing inside the CF significantly decreased and the number of naturally regenerated tree seedlings and saplings significantly increased. There were no other changes in forest management practices during the period that would affect natural regeneration, and there were no significant changes in the volume of wood harvested or the volume/number of standing trees (with a diameter at breast height ≥10 cm). We concluded that moderate intensities of forest grazing (0.4 cattle*ha^{-1}) and timber harvesting (4.64 m^3*ha^{-1}*y^{-1}) can be combined in this type of forest without negative impacts on forest regeneration. Our findings support Bhutan's policy of allowing forest grazing in CFs.*

Keywords: *Community forestry; forest regeneration; selection felling; forest policy; cattle grazing; Bhutan.*

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Introduction

Forest grazing is practiced in many parts of the world. In the European Alps, 15% of mountain forests are grazed during summer (Mayer et al 2006), whereas in the United States more than 75% of forests in some states have been grazed for 2 centuries (Wray 1998). Forest grazing reportedly has negative impacts on forest ecosystems, such as soil erosion, depletion of nutrients, soil compaction, and soil acidification (Belsky and Blumenthal 1997; Barnes et al 1998). Forest grazing has been reported to cause tree damage through trampling and browsing (Palmer et al 2004; Mayer et al 2006; Vandenberghe et al 2007) and loss of species richness and diversity (Fleischner 1994). In Switzerland, several cantons have enacted forest laws to discourage the practice of forest grazing (Mayer et al 2006).

However, many authors argue that forest grazing can be sustainable if grazing intensity is controlled (Krzic et al 2001; Pollock et al 2005; Mayer and Huovinen 2007). Forest grazing can enhance tree growth by reducing the biomass of grasses and sedges that otherwise outcompete tree seedlings (Belsky and Blumenthal 1997; Gratzer et al 1999; Darabant et al 2007). Grazing has also been reported to promote biodiversity (Mitchell and Kirby 1990; Mountford and Peterken 2003).

In Bhutan cattle are owned by 90% of households (Norbu 2000). Forest grazing contributes 22% of the national fodder requirement (Roder et al 2002) and is a vital component of Bhutanese agriculture, providing a critical source of phosphorous via manure (Roder et al 2003). However, forest grazing is widely considered to negatively affect the natural regeneration of broadleaved tree species in Bhutan (Van Ijssel 1990; Norbu 2000). Forest grazing after logging operations led to the replacement of valuable timber species with unpalatable nontimber species (Chamling and Pushparajah 1993; Davidson 2000; Seydack 2000). Positive effects of forest grazing have also been documented: forest grazing promoted regeneration of tree seedlings in conifer forests when grazing intensity was not too high (Gratzer et al 1999; Darabant et al 2007).

This study attempted to assess whether forest grazing and timber harvesting with selection felling can be combined sustainably in a cool broadleaved forest in Bhutan. Even though forest grazing is widespread in Bhutan, the intensity and impact of grazing has not yet been adequately quantified (Norbu 2000). This research was part of a larger study that also investigated the impact of traditional harvesting practices on the diameter distribution of the forest, diversity of tree species, and bole shape and form of remaining trees (Buffum et al 2008).

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Description of research area

Bhutan is a land-locked Himalayan country bordering with China (Tibet) and India, with an area of 40,006 km^2 and an estimated population of 672,425 (RGOB 2005). Yakpugang community forest (CF) is located in the Mongar District of eastern Bhutan (27°15′N; 91°16′E) and ranges in elevation from 1800–3200 m. Rainfall data are not available for the Yakpugang area, but the annual rainfall is estimated to be up to 3000 mm (Mongar Dzongkhag 2001). The forest is classified as a cool broadleaved forest (Grierson and Long 1983). It is dominated by *Quercus* and *Castanopsis* and includes at least 32 genera of tree species. The 260-ha CF was originally part of the adjacent 13,840-ha Korilla Forest Management Unit (FMU), which is commercially managed with cable crane logging operations. The CF was legally handed over to 113 households in 2001 through the new national community forestry program, which receives support from the Swiss Agency for Development and Cooperation through the Participatory Forestry Management Project. It was the second CF approved in Bhutan and the first to start timber harvesting operations. The CF is managed for timber, firewood, nonwood forest products, and forest grazing. Cattle are the major source of grazing pressure in the forest. The local residents do not graze yaks, sheep, goats, or horses in the forest. During the fieldwork we observed signs of wild boar (*Sus scrofa)* near the village, heard 1 barking deer (*Muntiacus muntjak),* and were informed that sambar (*Cervus unicolor)* is occasionally seen, but we did not observe signs of these animals in any of the inventory plots.

Methodology

Research approach

The study was based on a comparison of 2 forest inventories during a 5-year period and a household survey to assess changes in livestock holdings and grazing patterns. Yakpugang CF was an ideal location for the study because the grazing intensity was quantifiable due to a fixed number of households that utilize the forest and geographic features that delineate its borders. Furthermore, a forest inventory had been conducted in the same forest 5 years earlier. Replication of the study in additional forests would have strengthened the study, but we could not identify another broadleaved forest with baseline forest inventory data and a quantifiable forest grazing intensity.

Household survey

The household survey was administered to a random sample of households stratified by hamlet and socioeconomic group and including 27% of the 113 households. Data were simultaneously collected for the present time (2005) and 5 years earlier when the CF was legally established (2000). Although Bhutanese farmers can be reluctant to provide cattle numbers (Norbu 2000), we believe that the survey data are reliable because of the participation of village leaders and the positive relations with the community of one of the authors (YT) who served as the local forestry extension agent.

2005 Forest inventory

We conducted a forest inventory in 3 blocks of the CF that had similar site conditions and harvesting intensities. Each block had a rectangular shape with a narrow base (150 m) and longer sides (700 m) running up the slope, which included a greater harvesting intensity in the lower portion of the block (closer to the village). In each block, we established a systematic sample of 12 temporary inventory plots (total of 36 plots) in a regular grid ranging in elevation from 1920–2430 m.

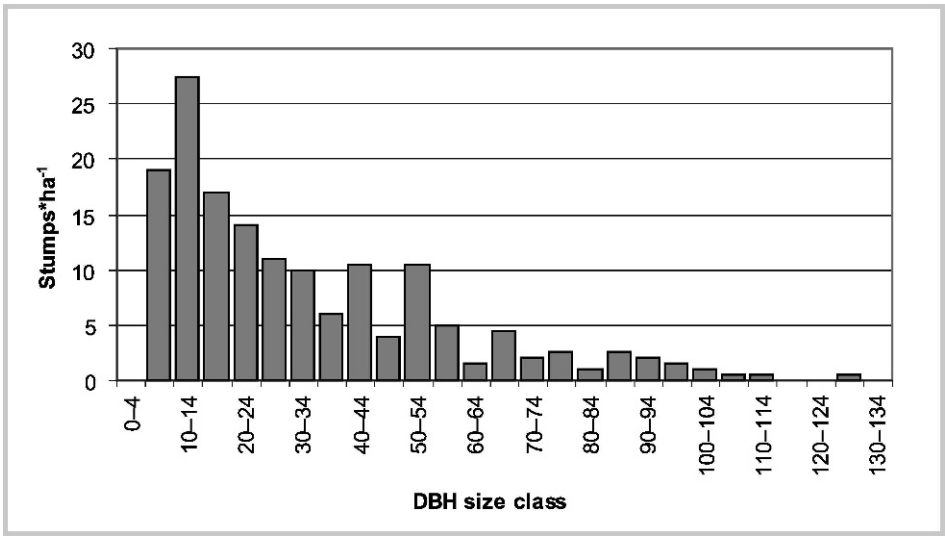
Each inventory plot included a 25 m × 10 m subplot in which all stems with height ≥1.3 m were measured. The plot layout followed the 1995 Department of Forests (DOF) guidelines for CF inventories (Demanski 1995), which were also used in a 2000 forestry inventory of the CF. The plots were laid out with the long sides perpendicular to the slope and with a 5 m × 5 m regeneration subplot in the center for seedlings with height <1.3 m. We established 2 additional subplots (25 m × 7.5 m) above and below each plot for additional data on timber-size trees (30 cm diameter at breast height [dbh] or greater). We recorded the species, diameter, and estimated age of all stumps in the entire 25 m × 25 m plots.

Tree volume was calculated using volume tables prepared for the adjacent Korilla FMU (FAO 1993). The annual allowable cut (AAC) for the current study was calculated using the approach of the management plan for Korilla FMU: AAC = (net operable area/rotation period) × (average standing volume/ha) (DOF 2005) and the same rotation period of 100 years. This method assumes that all trees are removed, and our study of stumps verified that the villagers harvest a range of size classes, with the largest number of stumps in the 10–14 cm dbh class, as can be seen in Figure 1.

The age of the stumps was estimated with the assistance of 2 local residents who were very familiar with logging operations in the forest and had worked as professional loggers in the adjacent commercially managed FMU. For each stump, a team of 3–4 persons estimated the year of harvesting by cutting into the stump with a machete and assessing the level of deterioration. We compared the AAC to the volume harvested during 5-year periods, but only included stumps harvested during the past 20 years as we were less confident about the ages of the older stumps. Whereas we recognized that dendroecological methods would have been more accurate, we believe that our subjective inspection was adequate for the purpose of this study. Stump diameter

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FIGURE 1 Number of harvested trees*ha^{-1} by size class.



was used as a proxy for diameter at breast height, as most stumps were approximately 1 m high. Taper studies have not been conducted for the species in the studied forest, but a study of broadleaved forests in Nepal reported that dbh was 94.4% of the diameter at 1 m height (Khatry Chhetri and Fowler 1996).

2000 Inventory

We utilized the data from a 2000 inventory that was conducted by the DOF as part of the CF management planning process. The 2000 inventory also followed the 1995 DOF guidelines for plot dimensions and provided comparable data on live stems, but no data on stumps. The 2000 inventory was based on a stratified sample of 26 temporary plots covering the entire CF. We used the data from the 12 plots that fell within our 2005 study area.

Statistical analysis

The data were analyzed with SPSS Version 15.0.1. We used Wilcoxon Signed Ranks tests to analyze paired samples of harvesting levels, livestock holdings, and grazing location and Mann–Whitney *U*-tests to compare the independent samples of the 2000 and 2005 forest inventories (Bailey 1995; Field 2005).

Findings

Forest development during 5 years

The studied forest included 39 tree species representing 32 genera and 22 families, with a basal area (BA) of 56 m^2*ha^{-1} and a standing volume of 559 m^3*ha^{-1}. The forest was dominated by 8 species that contributed 74% of the total BA: *Quercus semiserrata*, *Quercus lamellosa*, *Castanopsis hystrix*, *Persea clarkeana*, *Elaeocarpus lanceaefolius*, *Cinnamomum bejolghota*, *Exbucklandia populnea*, and *Symplocos ramosissima* (in descending order of BA). There were no significant differences ($P \leq 0.05$) between 2000 and 2005 in terms of the number of trees (dbh $\geq$ 10 cm), volume, or BA. However, the numbers of seedlings and saplings significantly increased during the 5-year period (Table 1). The frequency of timber species saplings, which are generally highly palatable to livestock (Davidson 2000), also increased.

Harvesting during 5 years

All but 5 of the 36 plots contained harvested trees, with an average density of 150 stumps*ha^{-1}. Nineteen of the recorded 39 species had been harvested. The most harvested species, which contributed 87% of the total BA harvested, were: *C. hystrix*, *P. clarkeana*, *Q. lamellosa*, *C. bejolghota*, *Q. semiserrata*, *Michelia doltsopa*, and *Elaeocarpus lanceaefolius* (in descending order of BA). The volume harvested annually during 2001–2005 was 4.64 $m^3*ha^{-1}*y^{-1}$ (2001–2005); differences to the previous time periods were not significant. In all 4 time periods during the past 20 years, the volume harvested was significantly lower than the AAC (Table 2).

Cattle holdings and grazing location

All but one respondent owned cattle, and most (73%) practiced forest grazing in the CF or other national forests. There was a significant decrease in livestock holdings per household between 2000 and 2005 (Table 3). The general trend was to replace local cattle with a smaller number of improved breeds (Jersey Cross and Swiss Brown Cross), which is being promoted by the Ministry of Agriculture throughout the country. The number of local cattle significantly decreased during the 5-year period, whereas the number of improved breeds significantly increased. According to the Yakpugang respondents, the main reason for reducing the number of livestock was a shortage of labor due to increased school

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TABLE 1 Comparison of seedling and sapling density*ha^{-1} in 2000 and 2005. (Note: Mann–Whitney *U*-Test, $N = 36$ [2005] and 12 [2000])

	2000	2005	Statistics
Median *N* seedlings	7636	12,864	$U = 126$, $P < 0.05$
Median *N* saplings (0–4 cm)	247	3275	$U = 3$, $P < 0.001$
Median *N* saplings (5–9 cm)	89	394	$U = 50$, $P < 0.001$
Median *N* timber saplings (0–4 cm)	67	924	$U = 50$, $P < 0.001$
Median *N* timber saplings (5–9 cm)	0	45	$U = 121$, $P < 0.05$

TABLE 2 Volume harvested compared with current annual allowable cut (AAC). (Note: Wilcoxon Signed Rank Test, $N = 36$)

	Harvesting time period			
	2001–2005	1996–2000	1991–1995	1986–1990
Median AAC ($m^3*ha^{-1}*y^{-1}$)	5.48	5.48	5.48	5.48
Median volume stumps ($m^3*ha^{-1}*y^{-1}$)	0	0	0	0
Statistics	$T = 156$, $P < 0.01$	$T = 98$, $P < 0.001$	$T = 37$, $P < 0.001$	$T = 0$, $P < 0.001$

TABLE 3 Changes in livestock holdings and grazing location between 2000 and 2005. (Note: Wilcoxon Signed Rank Test, $N = 113$)

	Grazing location	Year		Statistics
		2000	2005	
Median livestock holdings per household	Total livestock	7	3	$T = 38.00$, $P < 0.001$
	Local cattle	6	2	$T = 10.05$, $P < 0.001$
	Improved cattle	0	1	$T = 15.00$, $P < 0.01$
Median livestock holdings per household by grazing location	Community forestry	1	0	$T = 8.50$, $P < 0.05$
	Other national forest	0	0	$T = 8.50$, $P < 0.01$
	Private land	0	0	$T = 3.50$, $P < 0.001$

attendance and greater availability of seasonal employment for adults on government construction projects. None of the respondents claimed that the establishment of the CF had affected livestock holdings.

The location of grazing also changed during the 5-year period. The number of cattle grazing in the CF significantly decreased, as did the number grazing in other national forests, whereas the number of livestock grazed on private land significantly increased. This was because the improved breeds were generally stall fed or kept on private pastures in the village. The number of improved breeds grazing on private land increased 6-fold during the 5-year period. The number of traditional cattle grazing on private land also increased as the owners found it more convenient to keep their reduced livestock holdings closer to home.

The grazing intensity inside the CF, based on an overall CF area of 260 ha and a total of 113 households using the CF for grazing, was 1.4 livestock*ha^{-1} in 2000 and 0.4 livestock*ha^{-1} in 2005. The estimated grazing intensity applied to the entire CF and not specifically to the research blocks, but the occurrence of livestock trails throughout the CF suggested that the grazing intensity in the research area was representative of the entire CF. The number of animals grazing in other national forests owned by CF members also decreased significantly during

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the 5-year period, so there were no indications that the users protected their own CF by increasing the utilization of other national forests.

Discussion and conclusions

Tree regeneration is influenced by resource levels that may drive seed production and survival of trees. Whereas the former is at least partly influenced by weather conditions and the internal resource status of trees (Kelly and Sork 2002), resource-related factors leading to mortality are largely driven by the presence of suitable microsites (influencing mainly nutrient and water status) and the neighborhood (as a determinant of the radiation regime). Through management, both logging as well as grazing, the resource availability for seedlings is altered. In the present study, we found an overall increase of seedling and sapling densities. This could be an effect of changes in the management regime, weather conditions, or seed production. The most prominent change in the management regime during the 5-year period was a reduction in grazing intensity. Practices such as thinning or clearing underbrush that could have affected natural regeneration remained constant. Harvesting operations during the 5-year period did not cause any significant changes in the volume or number of standing trees with dbh >10 cm, and the volume of wood harvested during the period was not significantly different than earlier periods. Changes in weather conditions or seed production are unlikely to have been major factors because the increased regeneration applied to plants that germinated during a period of several years, including large saplings (5–9 cm dbh) as well as seedlings and small saplings. Assuming that insect herbivores and pathogens did not change with time, we attributed the overall increase in seedling and sapling density to the reduced grazing intensity.

The estimated 2005 grazing intensity of 0.4 cattle*ha^{-1} appeared to be below the threshold of sapling recruitment of the broadleaved species. This agrees with the estimated carrying capacity of 0.54 livestock unit (LU)*ha^{-1} in Nepal for temperate rangelands in Nepal associated with oak, mixed broad leaf, or bluepine (Pariyar 1995). The only genus in Yakpugang that did not exhibit adequate sapling recruitment was *Quercus*. Other studies in Bhutan have also noted the limited regeneration of *Quercus* in forests used for grazing (Miehe and Miehe 2002; Tashi 2004).

Similar trends of replacing traditional cattle with smaller numbers of improved breeds have also been observed in Nepal and the Indian Himalayas (Tulachan and Neupane 1999) as well as in other parts of Bhutan (Spierenburg 2003). However, the impact on total cattle populations varied: in the Indian Himalayas, as in Yakpugang, the total cattle population decreased, whereas in Nepal the cattle population continued to increase as the human population increased despite reduced per capita holdings (Tulachan and Neupane 1999). Nepal's livestock population is one of highest in the world in relation to the amount of arable land (Tulachan and Neupane 1999) and is estimated to be 13 times higher than the carrying capacity of temperate rangelands in the midhills (Pariyar 1995).

Controlled grazing inside CFs in Bhutan is generally permitted, whereas in Nepal it is generally prohibited. The decision in Nepal to prohibit grazing in the CFs undoubtedly contributed to the positive ecological impacts of the CF program, which include increased forest cover (Gautam et al 2002; Sakurai et al 2004) and increased stem density and natural regeneration (Yadav et al 2003). However, the impact on livelihood has been questioned: the increased forest cover in the CFs in Nepal may have actually reduced the availability of forage for livestock and forced members to reduce their cattle holdings (Dhakal et al 2005).

Bhutan, on the other hand, is in the enviable position of having a lower population density and 72.5% forest cover (DOF 2002). Our findings suggest that cool broadleaved forests like Yakpugang can be managed for timber with moderate levels of forest grazing without negative impacts on natural regeneration. Our findings support the policy of not prohibiting grazing in community forests in Bhutan and agree with other authors who argue that forest grazing can be sustainable as long as grazing intensity is controlled. However, the impact of forest grazing on *Quercus* needs further study.

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