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Regeneration and structure of mixed conifer forests under single-tree harvest management in the western Bhutan Himalayas

Mani Ram Moktan [a,*], Georg Gratzer [b], William H. Richards [c], Tek Bahadur Rai [d], Dawa Dukpa [d]

[a] Renewable Natural Resource Research Centre, Bajo, PO Box 1263. Wangdi Phodrang, Bhutan
[b] Institute of Forest Ecology, Department of Forest and Soil Science, University of Natural Resources and Applied Life Sciences, Peter Jordan-Straße 82, A-1190, Vienna, Austria
[c] Watershed Services Division, Seattle Public Utilities, 19901 Cedar Falls Rd. S.E., North Bend, Washington, USA, 98045
[d] Renewable Natural Resource Research Centre, Yusipang, PO Box 212. Thimphu, Bhutan

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ABSTRACT

We examined the regeneration and structure of mixed conifer forests under single-tree harvest management in western Bhutan. Sixteen 900 m^2 (30 m × 30 m) plots were sampled at four Forest Management Units (FMUs; Chamgang, Gidakom, Paro-Zonglela, and Haa-East) representing the forest type, including half the plots in single-tree harvest stands and half in unlogged stands. In addition, we solicited information on traditional forest management practices from informants using survey questionnaires and collected tree species data from felling records from respective local forest offices. Rural timber demand is concentrated on the removal of straight and well-formed bluepine trees for beams, planks, and scaffolding. Single-tree harvest, however, has not significantly altered stand structures from unlogged stands. Similarly, tree regeneration is not different when comparing single-tree harvest and unlogged stands, except at Chamgang FMU, where seedling densities were generally higher in harvested stands than in unlogged stands. These results indicate that single-tree harvest is not detrimental to regeneration and utilization of mixed conifer forests in western Bhutan.

1. Introduction

Mountain forests are a crucial resource for providing wood and non-wood forest products for mountain people, who in most regions of the world are economically marginalized (Price, 2005). Forests also protect watersheds and safeguard the supply of drinking water for nearly half of the world's population (FAO, 2003). Because of steep environmental gradients and biological significance, seven of the 18 global biodiversity hotspots identified by Myers (1990) are largely mountainous and about one third of the 785 million ha of the designated protected areas worldwide are located in mountains (Chakraborty, 2002). Due to the environmental risks of utilizing highly mechanised plantation forestry systems in steep mountain forests, it is often desirable to limit commercial forestry activities in mountain forests and protect sizable areas for conservation. Mountain forests, however, have traditionally been used by local communities with varying intensity and degrees of sustainability. Particularly in times of accelerated change of environment and land use patterns, it is important to analyse and assess the sustainability of current local forest use systems.

Studies in the central Himalaya of India and Nepal reveal that population pressure (both human and animal), changes in traditional land use practices, and continued extraction of raw materials (timber, fuelwood and fodder) decreases forest cover and productivity (Wakeel et al., 2005; Awasthi et al., 2003; Sundriyal and Sharma, 1995; Yadav, 2003). Sustainability of these forests, in terms of their intrinsic values as a life support system for local people, depends on their productivity, resilience, and intensity of use. Within the Himalayas, the forests of Bhutan are among the most poorly understood in terms of sustainable forest use. Single-tree harvest is the most common form of local timber extraction in these forests. This harvesting system has evolved from technical, logistical, and socio-economic constraints to meet the needs of forest users. Single-tree harvest, however, may lead to selective and concentrated removal of elite trees—a practice known in forestry as "high-grading" (Oliver and Larson, 1990), leaving crooked and diseased trees with little timber value (Daniel, 1980; Oliver and Kenady, 1982; Rickerd and Hanley, 1982).

In Bhutan, where almost all forests are Government owned, wood and non-wood forest products are sourced from natural forests that may or may not have management plans. Timber products include beams, planks, and scaffolding for house building, and poles for fencing and flags. Besides timber, leaf litter is used for cattle bedding, which is subsequently used for fertilizing agricultural land (Sargent et al., 1985), mushrooms used as vegetable (Namgyel, 1996), fuelwood is collected for cooking and heating (Dick and Yonten, 1995), and leaves are collected as fodder for cattle (Roder et al., 2003).

* Corresponding author. Tel.: +975 2 481209/481260; fax: +975 2 481311.
E-mail address: mrmoktan@yahoo.com (M.R. Moktan).

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Table 1
Plot and site characteristics of mixed conifer forests in western Bhutan.

Forest management unit	Longitude	Latitude	Altitude (m a.s.l.)	Aspect	Slope (%)	Temperature		Rainfall (mm/yr)	Parent materials/soils	Basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Stand description
						max	min					
Chamgang	89° 43′	27° 24′	2940	NW	25	24 °C at 2320 m	−3.4 °C at 2320 m	633 at 2310 m	Limestone, quartzitic, garnetiferous mica schist, and calc-silicate. Limestone soils are medium to fine texture with neutral pH and gneisses/quartzites soils are coarse texture and acidic (Dhital et al., 1992).	16	67	Single-tree harvest in 2003
Chamgang	89° 43′	27° 24′	2940	NW	30				–	27	95	Single-tree harvest in 2003
Chamgang	89° 43′	27° 24′	2900	SW	45				–	48	385	Unlogged
Chamgang	89° 43′	27° 24′	2940	SW	40				–	36	412	Unlogged
Gidakom	89° 30′	27° 23′	3330	N	50	25 °C at 2210 m	5 °C at 2210 m	561 at 2210 m	Limestone, quartzitic, garnetiferous mica schist, calc-silicate; Limestone soils are medium to fine with neutral pH and gneisses/ quartzites soils are coarse texture and acidic (Dhital et al., 1992).	36	111	Single-tree harvest in 2003
Gidakom	89° 30′	27° 23′	3320	N	20				–	49	158	Single-tree harvest in 2003
Gidakom	89° 30′	27° 23′	3340	N	45				–	110	302	Unlogged
Gidakom	89° 30′	27° 23′	3240	N	45				–	80	325	Unlogged
Paro-Zonglela	89° 20′	27° 17′	3200	N	30	26 °C at 2280 m	−1 °C at 2280 m	1037 at 2280 m	Pre-cambrian to tertiary series of meta-sedimentary migmatites and granitoid rocks; soils are sandy loam with moderate moisture (Slavicky, 1992)	19	95	Single-tree harvest in 2003
Paro-Zonglela	89° 20′	27° 17′	3200	N	50				–	36	154	Single-tree harvest in 2003
Paro-Zonglela	89° 20′	27° 17′	3160	NE	35				–	53	247	Unlogged
Paro-Zonglela	89° 20′	27° 17′	3160	NE	50				–	70	222	Unlogged
Haa-East	89° 17′	27° 23′	3300	SW	30	20.3 °C at 2712 m	−1 °C at 2712 m	731 at 2712 m	Pre-cambrian to tertiary series of meta-sedimentary migmatites and granitoid rocks; soils are rocky; well drained and acidic (pH 5.5) (Rinchen and Pushparajah, 1994)	39	130	Single-tree harvest in 2004
Haa-East	89° 17′	27° 23′	3280	SW	30				–	25	73	Single-tree harvest in 2004
Haa-East	89° 17′	27° 23′	3140	SW	45				–	43	232	Unlogged
Haa-East	89° 17′	27° 23′	3140	SW	60				–	45	229	Unlogged

Note: - denotes that parent materials and soils are same.