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Human interactions with forest landscape in the Khumbu valley, Nepal

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A B S T R A C T

High altitude Himalayan regions are geo-dynamically active and sensitive to natural disturbances. Nonetheless, even in this remote region, human pressure is often most important in influencing forest and landscape structure. In the last decades, fuelwood demand has risen due to increasing numbers of tourists and mountaineers. To understand human interactions with forest resources, stand structure and composition were examined at the landscape scale in the Sagarmatha National Park and its Buffer Zone in the Khumbu valley (Nepal). Using biological and historical data sources, a multi-scale approach revealed the influence of human activities on the distribution of tree species and forest structure. We sampled stand structure and environmental characteristics from 173 plots, and derived anthropogenic variables from thematic maps and satellite images for multivariate statistical analyses. Results suggest relationships among forest structure, anthropogenic influences, and topography. Low-density stands (100–150 tph) with sparse trees and rare big trees were in close proximity (0–36 m) to tracks and lodges. The wide variability in species diversity (0.67 at SNP and 0.58 at BZ) was strongly related to environmental factors, such as elevation, and human pressure. The frequent removal of green branches has adverse effects on tree growth, forest resistance, resilience, and regeneration capacity. We conclude that natural resources can adequately supply the local population needs, but current practices are not sustainable.

Introduction

Mountain landscapes are highly sensitive to natural hazards and disturbances due to their harsh geophysical characteristics and severe climatic conditions (Beniston, 2003). Their topographic complexity generates sharp gradients and abrupt climatic changes, in particular temperature and precipitation, over very short distances (Bugmann, 2001). The physical template (climate and topography) is commonly considered a principal factor in affecting vegetation structure and dynamics (Stephenson, 1990; Urban et al., 2000). Human influences play a major role, however, in shaping the structure of forest stands and landscapes even in remote mountain areas of the world.

Environmental fragility and seasonality of human activities, such as tourism, make mountain areas in developing regions particularly vulnerable to human-induced impacts (e.g. soil and vegetation trampling, disturbance to native wildlife, waste dumping) (Brohman, 1996). Tourism in mountain areas has increased in the last decades (Price, 1992) and is becoming a critical environmental issue in many developing countries (Geneletti and Dawa, 2009). This is particularly evident in Nepal, where increased pressures of tourism-related activities on forest resources and the biodiversity of alpine shrub vegetation have already been documented (Stevens, 2003). Sagarmatha National Park and its Buffer Zone (SNPBZ), a World Heritage Site inhabited by the Sherpa ethnic group and located in the Khumbu valley (Stevens, 2003), provides an example.

The Himalayan region, which also includes the Sagarmatha (Mt. Everest), has been identified as a globally important area for biodiversity (Olson et al., 2001) and is one of the world's 34 biodiversity hotspots (Courchamp, 2013). Over the past 50 years, the Sagarmatha region has become a premier international mountaineering and trekking destination. Related activities have caused adverse impacts on regional forests and alpine vegetation (Bjønness, 1980; Stevens, 2003), with over exploitation of alpine shrubs and woody vegetation, overgrazing, accelerated slope

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erosion, and uncontrolled lodge building (Byers, 2005). Large areas surrounding the main permanent settlements in the region are extensively deforested, with *Pinus wallichiana* plantations partly replacing natural forests (Buffa et al., 1998).

Despite the importance of the Sagarmatha region, few studies have examined sustainable management and environmental conservation of its fragile ecosystems, where ecological and socio-economic issues are strongly linked (Byers, 2005). The lack of knowledge about forest structure and composition, as well as human impact on the ecosystems, has frequently limited the implementation of sustainable management plans (MFSC, 2007; Rijal and Meilby, 2012). This study gathered quantitative data on forest resources and assessed the influences of human activities at Sagarmatha National Park (SNP) and its Buffer Zone (BZ). Using a multi-scale approach, we analyzed relationships among ecological, historical, topographic and anthropogenic variables to reveal the effects of human pressures on forest structure and composition. Specifically, we hypothesized that: (1) tourism and other human activities cause a reduction in diversity of both forest stand structures and tree species composition; (2) topographic constraints such as elevation play a fundamental role in shaping forest structure; (3) the establishment of a protected area such as the SNP has an important role for the conservation of forest resources in the Khumbu valley.

The results of this analysis enable a new assessment of possible management options for sustainability in fragile ecosystems in this area and elsewhere in the world.

Methods

Study area

This study encompassed both the core area (SNP) and buffer zone (BZ) of the National Park. Elevation of the study area ranges from 2300 m a.s.l. to 8848 m a.s.l. (Mt. Everest peak). The topography features very steep slopes and deeply incised valleys. The climate is strongly influenced by the summer monsoon regime with 70–80% of precipitation occurring between June and September (Salerno et al., 2010). Winters are generally cold and dry, while summers are cool and wet. The SNP extends for 1148 km^2, with rocks, glaciers, and tundra vegetation covering 69% of the total surface area (Bajracharya et al., 2010). Pastures (28%) and forests (3%) dominate the remaining area. Six vegetation zones occur along an altitudinal gradient: (1) lower subalpine forests (3000–3600 m a.s.l.) dominated by *P. wallichiana*, *Abies spectabilis* and *Juniperus recurva*; (2) upper subalpine forests (3600–3800 m a.s.l.) dominated by *Betula utilis*, *A. spectabilis* and *Rhododendron* spp.; (3) lower alpine shrublands (3800–4500 m a.s.l.) dominated by *Juniperus* spp. and *Rhododendron* spp.; (4) upper alpine meadows (4500–5500 m a.s.l.); (5) sub-nival zone (5500–6000 m a.s.l.); (6) nival zone (above 6000 m a.s.l.) (Fig. 1).

Human interactions in the Khumbu region began ~500 years ago when Sherpa people migrated from Tibet (Byers, 2005). For five centuries, they extensively applied irregular forest thinning on southern slopes, reducing the stem density by removing small and easily harvestable trees to obtain firewood, timber and to increase pasture areas (Stevens, 1993). A common properties system and the presence of Sherpa field guards ensured a sustainable use of forest resources (Byers, 2005). The Private Forest Nationalization Act in 1957, however, together with increased tourism and local population in the period 1950–1980, caused significant land use changes due to the growing demand for timber and firewood (Byers, 1997, 2005). In the last thirty years, the number of tourists has increased further, but its impact on the SNP forest landscape is still not clear. Socio-economic, anthropological and geographic studies reported "widespread deforestation" caused by human pressure in the Sagarmatha region (e.g. Bjønness, 1980; Garratt, 1981; Hinrichsen et al., 1983; von Fürer-Haimendorf, 1984). More recent studies (Stevens, 2003; Byers, 2005) have reported different conclusions. With the establishment of the Sagarmatha National

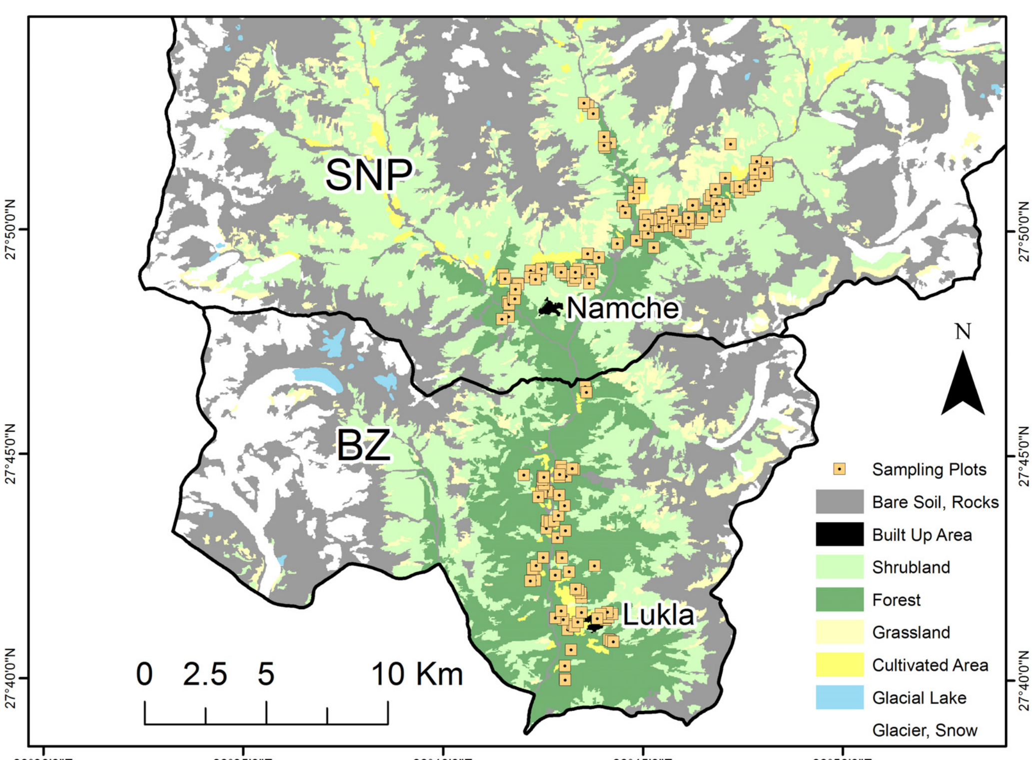

Fig. 1. Land cover map of Khumbu valley divided by site (Sagarmatha National Park – SNP, and Buffer Zone – BZ) derived from satellite images (Bajracharya et al., 2010). 173 temporary field plots (red dots) were randomly located within the "forest" land cover category.