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Forage yield and cattle carrying capacity differ by understory type in conifer forest gaps

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ABSTRACT

A study was conducted in the Himalayan mixed conifer forests to generate estimates of cattle carrying capacity of logged sites, using consumable forage dry matter and nutrient content. Field samples were collected from four major understory vegetation types dominated by *Yushania microphylla* (ground cover proportions of 100% and 50%), *Rubus nepalensis*, *Synotis alata* and *Sambucus adnata*. The amount of dry matter, total digestible nutrient and digestible crude protein removed by cattle grazing was highest for the vegetation with 100% *Y. microphylla*. Vegetation with *S. adnata*, *S. alata* and *R. nepalensis* provided low consumable dry matter yield and nutrient content per hectare area. For vegetation with 100% *Y. microphylla*, based on consumable dry matter, total digestible nutrients and digestible crude protein, the cattle carrying capacities were estimated at 4.17, 2.27 and 1.27 Livestock Units per Year (LUY) per hectare, respectively. Vegetation with 50% *Y. microphylla* provided about one LUY per hectare both in terms of consumable DM and nutrient content. Vegetation with *S. alata* also provided nutritional carrying capacity of about one LUY per hectare but the carrying capacity in terms of consumable dry matter was lower than one LUY per hectare. Cattle carrying capacity, both in terms of dry matter and nutrient content was lower than one LUY per hectare for vegetation with *S. adnata* and *R. nepalensis*. We concluded that, depending on the type of understory vegetation, carrying capacity differs within hemlock-dominated mixed conifer forest in the Eastern Himalaya. Forage utilization was higher for *S. alata*, *S. adnata* and *R. nepalensis* vegetation, suggesting the need for vigilance to avoid overgrazing in these vegetation types. The study indicates the opportunity to select appropriate carrying capacities allowing optimum cattle density and providing the required level of nutrition, while avoiding over-grazing. We recommend our estimates to be used as guide to better understand the carrying capacity of logged sites in the Himalayan conifer forest.

1. Introduction

Ecosystems' responses to disturbances vary across spatial and temporal scales. The response to anthropogenic disturbances depends on site productivity, with poor sites being less resilient to anthropogenic changes than more productive sites (Larson and Paine, 2007). Herbivory is a key process that determines ecosystems' resilience (Adam et al., 2011), structure and function (Manier and Hobbs, 2007). In forest ecosystems, the tree-herbivore balance is a fundamental issue and may require certain level of anthropogenic influences for coexistence (Roininen et al., 2007). However, management for harmonious tree-herbivore equilibrium is a challenge (Roder, 2002; Mountford and Peterken, 2003) and often leads to conflicts of interests when deciding on how to manage the system involving livestock and forest. Under such situations, quantitative evaluation of habitat is extremely important to facilitate proper management (Hanley and Rogers, 1989; Mizutani, 1999).

Globally, forest ecosystems are subject to recurrent disturbances and resource exploitation, causing radical change. More than natural factors, management methods are driving forest ecosystems (Berg et al., 2008), leading to formation of forest gaps. Forest gaps are characterized by high herbaceous vegetation cover (Modrý et al., 2004) and abundant herbage (Mayer and Stockli, 2005), which are preferentially grazed by cattle (Carman and Briske, 1985) and wild life (Kuijper et al., 2009). Depending on

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spatial heterogeneity and foraging behavior along the environmental gradient, herbivores have different impacts on ecosystems (Stuart-Hill, 1992). Thus, the effects of ungulate herbivory are reported to be both beneficial (Gratzer et al., 1999; Humprey and Patterson, 2000; Roder, 2002; Luoto et al., 2003; Peco et al., 2006; Casasus et al., 2007; Darabant et al., 2008) and deleterious (Patric and Helvey, 1986; Broersma et al., 2000; Wangda and Ohsawa, 2006). Deleterious effects are often associated with overgrazing by wildlife and domestic herbivores (Mysterud, 2006). Overgrazing is reported to be counterproductive, causing adverse effects on soil (Patric and Helvey, 1986; Broersma et al., 2000; Sharrow, 2007) and vegetation (Haeggstrom, 1990; Broersma et al., 2000; Mayer et al., 2006; Pande and Yamamoto, 2006). While deleterious effects are debated in frequent disputes, management frameworks to address these issues are less emphasized, particularly with reference to logged sites in temperate forest ecosystems. A number of studies suggest measures to counteract the adverse effects of overgrazing such as grazing exclusion (Shrestha and Stahl, 2008; Fernández-Lugo et al., 2009; Li et al., 2012), adjustments in grazing duration (Savadogo et al., 2007), stocking rate (Nomiya et al., 2002), and rotational grazing (Royal Government of Bhutan, MoA, 2006). However, these measures are applied widely only on grasslands and less on forest ecosystems. Besides, the measures need to be cost effective, providing opportunities for both resource conservation and utilization. Defining threshold levels for herbivore density which are based on a quantitative assessment of grazing resources might be feasible, without diminishing returns from forest utilization (Jorritsma et al., 1999). Depending on landscape conditions and site productivity, the thresholds of herbivore density vary from one ecosystem to another (Afzal et al., 2007; Chaudhry et al., 2010; Robinson et al., 2010), indicating the need for quantitative assessment of the respective ecosystems.

Estimates of animal carrying capacity (Baars and Jeanes, 1997; Afzal et al., 2007; Savadogo et al., 2007; Chaudhry et al., 2010; Robinson et al., 2010; Hajno and Tahiri, 2011) have been successfully used in management decisions and planning (Mayer et al., 2006) and help to achieve sustainable utilization of ecosystems (Stoddart et al., 1975; Kuzyk et al., 2009). Animal carrying capacity is defined as the maximum stocking rate that a certain land area can support on a sustainable basis during a defined grazing season (FAO, 1991). Carrying capacity was estimated using nutritional parameters besides forage biomass in several studies (Hobbs et al., 1982; Thapa and Paudel, 2000; Beck et al., 2006; Das and Shivakoti, 2006). A sound estimate of carrying capacity might promote sustainable management for optimum production of livestock and timber (Roder, 2002; Pollock et al., 2005; Buffum et al., 2009), and may contribute to finding a long term solution to resolving existing conflicts.

This paper presents the results of a study conducted on logged sites in the mixed conifer forests of Bhutan, where forest grazing by cattle is perceived to negatively affect tree regeneration and is viewed as a main constraint to good forest management (Roder et al., 2002). The ability to resolve conflicts has been limited by the lack of scientific data on thresholds for cattle density, which would allow for a sustainable forest management. Therefore, our primary objective was to estimate the cattle carrying capacity of logged sites in the mixed conifer forest, using the amount of consumable forage dry matter and its nutrient contents as main parameters. Since mixed conifer forests have different understory vegetation, we aimed to generate estimates of cattle carrying capacity of dominant understory vegetation. The study is an attempt to contribute to a better understanding amongst resource managers on the cattle carrying capacity for sustainable management of logged sites in mixed conifer forests.

2. Materials and methods

2.1. Study sites

We selected Gidakom Valley as study site, representing the mixed conifer forests in Bhutan. The forests supply wood and non-wood products to the urban areas and adjacent rural households in the district of Thimphu. Both sedentary and migratory livestock are fully dependent on forest grazing in the study areas. The presence of wildlife based on ocular assessment of droppings seems comparatively negligible. For livestock grazing management, farmers practice deferred grazing of permanent grassland, use of tree fodder species during the dry season and seasonal migration to lower elevations. Forest grazing is one of the main sources of ruminant feed. Fallow land grazing is often practiced after crop harvest where cattle are allowed to graze freely in the crop fields as soon as crops are harvested. The fallow lands are extensively grazed during acute shortages of fodder in winter. Crop residues are used as traditional winter fodder.

The Forest Management Unit of Gidakom lies in western Bhutan between Thimphu and Paro valleys with a total area of 13,000 hectares and 115 households (Dhital et al., 1992). The study area (89° 29'N, 27° 27'S; 3220 m elevation) is located in the Forest Management Unit, where commercial harvesting started 20 years ago. Topography is rugged and the mean maximum temperature of 25 °C is recorded in the month of July and the mean minimum of 5 °C in January. The average annual rainfall is about 622 mm, mostly in the months from June to August (Dorji, 2004). The main tree species include Eastern Spruce (*Picea spinulosa*), Himalayan Hemlock (*Tsuga dumosa*) and Brown Oak (*Quercus semecarpifolia*) mixed with Blue Pine (*Pinus wallichiana*). The main understory species comprise *Yushania microphylla*, *Synotis alata*, *Salvia campanulata*, *Sambucus adnata*, *Rubus nepalensis* and *Senecio raphanifolius*. Unlike other understory vegetation, *Y. microphylla* is evergreen but remains dormant in winter.

2.2. Selection of experimental plots

We classified the understory vegetation by analysing the plant inventory data of 90 forest openings, using the CANOCO software. The average size of the forest opening was 0.15 ha. The analysis segregated the logged openings into homogeneous groups of dominant species representing the vegetation of the forests under study. The major species were *Y. microphylla, R. nepalensis, S. alata* and *S. adnata*. *Y. microphylla* and *S. alata* are grazed by cattle; *R. nepalensis*, although consumable forms a thick mat on the forest floor and is barely grazed and *S. adnata* is a non-forage species. Given the varying levels of dominance and patchy occurrence of *Y. microphylla* in the mixed conifer forests, we purposively sampled two different proportions of vegetation dominated by this species i.e 100% and 50% plant ground cover. Except for *Y. microphylla* which is evergreen, all dominant vegetation were deciduous in nature. The annual growth cycle of major understory vegetation types except *Y. microphylla* is generally characterized by bud break in spring and culminating in leaf fall in autumn, followed by dormancy in winter.

We selected 10 logged forest openings for field measurement and sampling. Two openings were assigned to each dominant vegetation type. The sample plots were located in the center of each opening. Each opening constituted one block, consisting of one pair of grazed and ungrazed plot of 2 m × 2 m. The ungrazed plots were fenced after logging.