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Intensity of browsing on trees and shrubs under experimental variation of cattle stocking densities in southern Bolivia

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ABSTRACT

Mountain forests are traditionally used for cattle grazing during the dry season in southern Bolivia. To evaluate browsing intensity and damage to young trees and shrubs, a forest grazing area was monitored for about 3 months in both 2006 and 2007. Three similar paddocks of about 3 ha each, consisting of grassland and forest in a ratio of about 1:3 were stocked with 0.9, 1.6 and 2.6 tropical livestock units per ha (equivalents of 250 kg of body weight), reflecting low, medium and high stocking densities. Six 5 m × 5 m plots were mapped out within each paddock in 2006. Three additional plots per paddock were added in 2007. Within plots, the individuals of 18 woody species were coded and evaluated weekly for intensity of browsing. Intensity was quantified using five-scale categories reflecting the proportions of plant tissue removed (0 = no browsing, 1 = 1–25%, 2 = 26–50%, 3 = 51–75% and 4 = 76–100%). Across all plant species, the average category of browsing intensity, as determined in the post-grazing evaluation, was affected ($P < 0.001$) by stocking density. Browsing intensity increased in an approximately linear manner from 1.58 to 2.18 and 2.77 with low, medium and high stocking density, respectively. There was no significant difference between years. Most woody species followed the same general response pattern to stocking density, although some species were only noticeably browsed at high stocking density while a few others were intensively browsed at all stocking densities. The onset of browsing on woody species was observed only after some weeks had passed, indicating that herbaceous plants were preferred as a forage resource. The proportion of fatally damaged individuals, as assessed about 8 months after grazing in 2006, were 10.6%, 8.6% and 11.4% for low, medium and high stocking density, respectively. The percentage of completely browsed individuals increased with stocking density, but 80% of those plant individuals recovered following a resting period of 8 months. However, although most woody species recovered from browsing and fatal damage was infrequent, long-term changes in woody plant species composition and structure caused by grazing cannot be excluded. High stocking density in particular may reduce the vigour of heavily browsed species.

1. Introduction

Livestock grazing and browsing in forest environments is practized in many parts of the world, such as Switzerland (Mayer et al., 2005, 2006), the Mediterranean region (e.g., Israel, Dufour-Dror, 2007), Asia (e.g., Bhutan, Roder et al., 2002) or Latin America (e.g., Argentina; Relva and Veblen, 1998). In general, attitudes towards forest grazing are variable, with factors such as livestock species, period of grazing, grazing intensity in relation to the ecosystem and its characteristics, and the motivation behind allowing or prohibiting grazing all being influential. Acceptance of forest grazing as a viable practice therefore depends greatly on the degree of ecosystem damage that this type of agriculture is prone to inflict in a given area.

Goats are of the intermediate feeding type (Hofmann, 1989) and would be expected to browse on most of the available woody species in a forest ecosystem. In contrast, cattle are typical grass and roughage eaters (Hofmann, 1989) and would therefore be predicted to prefer grasses over trees and shrubs, if available, in forest grazing lands. However, static hoof pressure for cattle is higher than for sheep or goats (Willatt and Pullar, 1983; Greenwood and McKenzie, 2001); therefore, cattle may cause

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greater damage by trampling than they do by grazing. Differences in selection behaviour, i.e., preference for or avoidance of individual woody species by livestock, may also play a role in determining the level of effect of grazing on forest species (Sun et al., 1997; Mayer et al., 2005; Cierjacks et al., 2008). The amount of alternatively available vegetation may also be important in this respect (Relva and Veblen, 1998). Time of grazing and/or duration also influences the degree of the effect of livestock grazing on forest vegetation (Hall et al., 1992; Dockrill et al., 2004; Mayer et al., 2005; McEvoy and McAdam, 2008). The characteristics of the forest environment itself are also decisive. In certain environments, grazing can even improve the growing conditions for young trees through a direct or indirect reduction of the density of upper vegetation layers (Miller and Wells, 2003; Mayer and Stöckli, 2005; Darabant et al., 2007). However, in other areas such as for instance a Mediterranean Tabor oak forest, grazing can lead to a reduction in density of young tree saplings (Dufour-Dror, 2007).

Controlled grazing experiments are considered as useful tools for the assessment of the impact of large herbivores on forest ecosystems, and are especially recommended for assessing the influence of different grazing intensities (Hester et al., 2000). Experiments dealing with differing livestock intensities and their impact on young trees have been conducted in several studies (e.g., Hall et al., 1992; Hester et al., 1996; Mayer et al., 2005, 2006; Vandenberghe et al., 2007). However, no such information exists for the type of ecosystem selected for the present study, represented by the Boliviano-Tucumano mountain forest of southern Bolivia. In this region, cattle forest grazing has been practised for centuries in a transhumant system (Vacaflores et al., 2003). Within this system, cattle spend almost half of the year, i.e., the period of the dry and the prehumid season (late autumn–early spring), in the mountain forests because of the rapid decline in forage in the grasslands that area grazed in the rainy season.

The present study records the browsing intensity by cattle on various tree and shrub species following experimental variation of stocking density (livestock units ha^{-1}; Pitt et al., 1998). The main objective was to determine whether an increase in cattle stocking density will affect browsing intensity in a linear way over time in a drought-deciduous forest with adjacent pasture, which is characteristic of both components of the local transhumant system (grassland used in the rainy season and forest areas in the dry and prehumid season).

2. Methods

2.1. Study site and experimental design

The experiment was conducted in southern Bolivia, Department of Tarija, Province O'Connor, community of Salinas. In this region, a transhumance system is practised. During the rainy season, the cattle stay on the grasslands in the Salinas valley (approx. October/November to April/May). With the beginning of the dry season, the cattle are moved to the mountain forests. When rainfall leads to regrowth of the grassland forage resources, the cattle are moved back to the grasslands (October/November).

The experiment was conducted in two subsequent years (2006 and 2007), always from the beginning of March to the end of May/beginning of June (85 days). The goal was to cover the period of transition from grazing on the open pastures to grazing forested areas. Climate data were recorded in 2007 using a meteorological station installed in the open pasture of the experimental are (21°45′05.6″S and 64°12′10.6″W; 1259 m a.s.l.). In March, April and May 2007, the mean temperature was 22.5, 19.5 and 13.1 °C and precipitation accounted for 147, 65 and 19 mm, respectively.

The experimental area (9.4 ha in total) selected in the hills above the Salinas valley reflected both typical grassland and forest area as used for grazing in the rainy and the dry periods, respectively. The area chosen had been grazed in the preceding years, but was excluded from grazing by fencing for 9–10 months prior to this experiment, and also between the experimental grazing periods in 2006 and 2007. The latter procedure allowed the area to rest from grazing for about the same period as it had in the preceding year. The grassland area was flat on a plateau at 1259 m a.s.l., whereas the woodland declined with occasionally steep slopes to a small canyon with a small creek. On the other side of the creek, the woodland continued. Forest made up about 75% and grassland 25%. The latter was interspersed with groups of small trees and shrubs, mainly *Acacia aroma* and *Dodonaea viscosa*. The main grass species found in the grassland area were *Paspalum notatum* and *Axonopus compressus*.

The experimental area was divided into three similar paddocks (3.03, 3.18 and 3.15 ha) with grassland and forest representing approximately the same proportions. The three paddocks were stocked with three different cattle stocking densities (SDY; in the order of medium, low and high), with 6, 3 and 9/8 animals in 2006 and 2007. Due to the natural limitations of the experimental area, it was not possible to replicate the SDY within the same year. Thus, the experiment was conducted in two consecutive years under the same conditions, with each year considered as a replicate.

Within each experimental paddock, six open plots (5 m × 5 m each, sometimes up to 6 m × 5 m at steeper slope gradients) were installed. Two plots were selected at each of three altitudinal levels: (i) the upper part of the slopes (approx. distance of 30–40 m from the grassland), (ii) the middle part of the slopes, and (iii) the area across the creek furthest from the grassland. In 2007, all pairs of experimental plots, at each altitude and paddock, were supplemented by another plot, to give a total of 27 plots for that year. This was done in order to enlarge the dataset for the comparison of browsing intensity of the woody plant species.

2.2. Tree species investigated

In total, 18 different tree and shrub species were selected for the investigation of the effect of cattle SDY on browsing intensity (Table 1). These species were identified in a preliminary study in February 2006 as being browsed within a 5-day trial period, with five cattle kept in the proximity of the experimental area. Although there were naturally occurring variations in the numbers of each species in each plot, the proportions of each chosen tree or shrub species in terms of total plant numbers of the 18 investigated species were not significantly different among plots. Overall, the 18 chosen plant species made up at least 50% of all tree/shrub individuals ($\leq$2 m) found inside the experimental plots.

2.3. Experimental animals

The local Criollo cattle used for the experiment had been grazing in open pastures in the Salinas valley prior to the experimental periods. The experimental paddocks were stocked with (i) two adult cows, one calf (low SDY), (ii) three cows, one male, two calves (medium SDY) and (iii) five/four (in 2006/2007) cows, one male, three calves (high SDY). Most of the experimental animals were exchanged between years. The few animals that were used again were allocated to different paddocks in the second year. Stocking density with tropical livestock units (TLU, equivalents of 250 kg of body weight) were calculated from body weights of all animals, measured with a portable digital cattle balance prior to the experimental periods. The realised TLU ha^{-1} were almost equal in 2006/2007 with 0.90/0.89, 1.60/1.57 and 2.62/2.61 at low, medium and high SDY, respectively. In 2007, due to feed scarcity, grazing in the paddock with the high SDY had to be ended 1 week earlier than intended. For the same reason, one cow with her calf