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Influence of cattle stocking rate on browsing of Norway spruce in subalpine wood pastures

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Abstract

In the Swiss Alps, 15% of Swiss mountain forests are grazed during summer, mainly by cattle. The forest laws of various Swiss cantons characterise forest grazing as a detrimental form of land use and stipulate that this grazing practice should be restricted. However, little is known about tree damage actually caused by cattle. Seven subalpine ranges in the Swiss Canton Grisons, grazed by cattle at different stocking rates, were investigated. The condition of naturally regenerated young trees (*Picea abies* (L.) Karst.) was assessed before and after the cattle grazing period. In order to characterise the influence of wild ungulates on the young trees during winter, the assessment of tree condition was repeated in the proximate spring. In total, 4% of the young trees were browsed on the apical shoot, 10% were browsed on lateral shoots, 13% of the trees showed other damage. The variation among ranges could almost completely be explained by the cattle stocking rate (livestock units per hectare). During winter, wild ungulates browsed 3 times as many young trees as the cattle during summer. The results suggest that cattle stocking rates on subalpine wood pastures should not exceed one livestock unit per hectare in order to avoid intensive browsing and other damage by cattle on young Norway spruces.

Introduction

At present, 15% of Swiss mountain forests are grazed during summer, mainly by cattle. The wood pastures used by Swiss farmers usually comprise wooded areas, half-open areas, and open areas. Most of the subalpine forest included in the wood pastures is forest with declared protective function against natural hazards. As forest grazing may retard forest regeneration by trampling and browsing of young trees, which could reduce this protective function, the forest laws of various Swiss cantons stipulate that forest grazing should be restricted and, whenever possible, terminated (e.g. Anonymous 1996). The forested area in the Swiss Alps has expanded by about 30% during the 20th century (Brändli 2000). In the 19th century, in addition to cattle and other domestic stock, large herds of goats used the subalpine zone for grazing, even in late autumn and early spring. There is general agreement that the abandonment of agricultural land and the reduction of livestock

numbers is the main reason for this forest expansion. Little is known about the influence of the present extensive cattle grazing on the regeneration of young trees in subalpine forests. Liss (1988) and Huntsinger (1996) emphasised that tree browsing by wild ungulates in winter might exceed tree browsing by cattle. Wild ungulates are known to cause severe browsing damage to young trees in winter (Motta 1996). Cattle, which stay on subalpine wood pastures only during part of the growing season, are known to prefer herbaceous species compared to tree shoots, and thus are classified as grazers rather than as browsers (Hofmann 1989). Liss (1988) and Huntsinger (1996) found that cattle avoided browsing shoots of Norway spruce (*Picea abies* (L.) Karst.), though Haeggström (1990) observed that animals begin consuming less palatable plants, such as spruces, when grazing intensity is high. A certain extent of browsing on Norway spruce is tolerated, though, before structure and composition of forests are considerably altered. Eiberle and Nigg (1987) stated that apical shoot browsing should not exceed 12% of the young trees per year to ensure the regeneration of Norway spruce in montane forests.

In the present study, tree browsing and other damage caused by cattle were quantified on subalpine wood pastures. Furthermore, on part of the sample trees the extent of tree damage by wild ungulates, mainly red deer (*Cervus elaphus*), in winter was assessed.

Materials and methods

Experimental ranges and stocking regime

The study was carried out in the Dischma valley (46°46′ latitude N; 9°53′ longitude E) near Davos in the Swiss Canton of Grisons. There is a large variety of adjoining wood pasture ranges traditionally grazed with cattle at different stocking rates. No sheep and goats were present on the ranges. As the region is located at the transition between the central Alps and the northern part of the Alps, the climate has aspects of both continental and oceanic. Compared to other Alpine regions, the precipitation is relatively low with 1050 mm per year. As 40% of the precipitation is snow and slopes are relatively steep, avalanches are frequent in the Dischma valley. The mean temperatures in January and July are $-7\,^{\circ}C$ and $+12\,^{\circ}C$, respectively. The substratum in the Dischma valley is crystalline, and the forest is dominated by Norway spruce (Bosshard 1986).

Seven ranges, located between 1560 and 2000 m a.s.l. and covering all types of wood pasture management practised at this altitude, were investigated. Table 1 provides detailed information on the site and grazing characteristics of the ranges. Almost half of the area of the ranges was woodland, 25% was half-open area (with young trees and shrubs) and 31% was open area. The average forest density of the woodland area differed among ranges. The forests became gradually less dense towards the open area (data not shown in table). Depending on altitude, aspect and weather conditions of the respective year, the ranges could be used for grazing during around 3 months in summer, from June to September, in some years even until mid of October. Table 1 gives the main grazing months for the ranges investigated. The cattle stocking rate in summer 2000 ranged from 0.4 livestock units (LU; i.e., 600 kg body weight) per hectare (ha) to 2.8 LU ha^{-1}.

Tree selection and assessment of tree condition

For the selection of the sample trees, each of the seven ranges was subdivided into $50\,m \times 50\,m$ squares and at the intersections the nearest young tree within a 10-m radius was selected and marked as a sample tree. In total, 165 naturally regenerated young trees (153 Norway spruces (*Picea abies* (L.) Karst.), nine European larches (*Larix decidua* Mill.) and three rowans (*Sorbus aucuparia* (L.)) were systematically selected. Thirty, 20, 43, 9, 13, 33 and 17 sample trees, respectively, were selected on Ranges 1–7. Only trees from 0.3 to 2.5 m in height were considered since larger trees were assumed to be out of reach for browsing on apical shoots and to be much more resistant to other damage by cattle. Trees <0.3 m tall were too difficult to be reliably marked and to be found again at every measurement date. Furthermore, seedlings and saplings below this height are influenced much more intensely by natural environmental factors than by grazing effects (Rooney et al. 2000).

Table 1. Characterisation of the ranges investigated in Dischma valley, Grisons, Switzerland.

Characteristic	Range							Average
	1	2	3	4	5	6	7	
Open area (%)	50	40	44	18	18	23	22	31
Half-open area (%)	0	0	14	68	68	23	50	25
Woodland area (%)	50	60	42	14	14	54	28	44
Forest density (trees ha^{-1})	350	100	300	250	250	200	200	
Forest type (species)[a]	P	P	P	P	P	PL	PL	
Size (ha)	6.5	1.0	19.3	3.0	3.4	9.3	5.4	6.8
Aspect (exposure)	South	North	North	South	South	South	South	
Cattle breed[b]	BS	BS	BS	RG	RG	RG	RG	
Cattle category	heifers	cows	cows + heifers	cows + heifers	cows + heifers	cows + heifers	cows + heifers	
Cattle numbers per category	16	7	8 + 4	7 + 3	7 + 3	7 + 3	7 + 3	
Main grazing months	June, Sept.	June, August	July–Oct.	July	August	July–Sept.	August, Sept.	
Grazing days	41	78	114	10	12	64	32	
Stocking rate (livestock units ha^{-1})[c]	1.0	1.2	0.5	2.8	1.6	0.5	0.4	
Altitude (m a.s.l.)								
Min.	1600	1560	1580	1720	1800	1850	1950	
Max.	1700	1580	1700	1800	1850	1950	2000	

[a]P – *Picea abies* stand; PL – mixed stand of *Picea abies* (dominating) and *Larix decidua*.
[b]BS – Brown Swiss; RG – Rhatisches Grauvieh.
[c]Stocking rate during the grazing days given in the table, as valid for summer 2000.

Tree condition was assessed by various shoot length measurements and by recording of tree lesions. In detail, the total height of the sample trees, the length of the apical shoot and the length of time lateral shoots (± 0.5 cm) at different heights were measured. Lateral shoot browsing was assessed using an intensity scale consisting of four categories: 0–20%, 21–40%, 41–60% and over 60% of the lateral shoots browsed. Additionally, it was registered whether or not the apical shoot was browsed, and whether the sample trees had other damage, such as broken lateral shoots, trampling marks, or fraying scars. As a baseline, all existing tree lesions due to previous grazing activities of domestic animals and wild ungulates were recorded immediately before the respective cattle grazing periods. After the cattle grazing period on the respective ranges, the tree condition was assessed again, and changes in tree condition were interpreted as damage mainly caused by cattle. In summer, before cattle grazing starts, red deer move to the alpine area mainly on the northern slope, and they use the lower subalpine ranges until early spring only, when the grass starts growing (Silvio Sprecher, personal communication). During the hunting period in September, most of the red deer move to the game preserve. Thus, usually red deer do not use the wood pasture ranges for grazing during the cattle grazing period. Roe deer (Capreolus capreolus) is infrequent in the region. Chamois (Rupicapra rupicapra) lives mainly in the alpine area and uses the subalpine area in winter only (Silvio Sprecher, personal communication). This means that wild ungulates usually do not use the wood pasture ranges for grazing during the cattle grazing period, and summer browsing on the sample trees by wild ungulates is not likely. However, in winter the study area is known to be frequently used for browsing by chamois, few roe deer and large groups of red deer (Bosshard 1986). In April 2000, approximately 100 red deer were counted in the whole Dischma valley (Silvio Sprecher, personal communication). Supplementary winter feeding of red deer is a common practice throughout Europe, and is normally associated with maintaining high densities of animals in the respective region (Putman and Staines 2004). As shoots of young trees are an important feed source for wild ungulates during winter, we assessed the tree damage caused by wild ungulates in the period from late autumn to early spring. For this purpose, on Ranges 1, 2, 3, and 6, where the last assessment of the tree condition after cattle grazing was made end of September 2000, the assessment of tree condition was repeated in the end of May 2001.

Statistical evaluation

Simple linear regression analysis was applied to evaluate correlation of browsing and other damage and stocking rate. The analyses were carried out using the statistics programme Systat (SPSS 1996).

Results

Browsing and other damage by cattle

On average across all ranges, 13% of young trees were browsed within the cattle grazing period in 2000. This rate ranged from 3% on Range 6, which was grazed by less than 1 LU ha^{-1}, to 22 and 23% on Ranges 4 and 5, which were grazed by 2.8 and 1.6 LU ha^{-1}, respectively (Table 2). Only in one tree there were both apical and lateral shoots browsed, and none of the trees was fatally damaged by cattle browsing. The browsed trees were shifted to the next higher browsing category only. Apical shoot browsing was found on 4% of the sample trees, Tree damage during the cattle grazing period due to reasons other than browsing (fraying, trampling and breaking) was nearly equal to that of damage from browsing (Table 2). No tree was both, browsed and otherwise damaged. Only one sample tree was fatally damaged by trampling, and in all other cases, the trampling scars caused by cattle were vertical and relatively short (max. 3 cm in length).

Browsing and other damage by wild ungulates

During winter 2000/2001, the percentage of trees browsed by wild ungulates on Ranges 1, 2, 3, and 6 was nearly 3 times as high as that found in the preceding cattle grazing period. Damage other than browsing occurred infrequently during winter (Table 2).

Table 2. Percentage of browsing and other damage by cattle and by wild ungulates (the values give the percentages of trees investigated).

Source of damage	Range							All ranges
	1	2	3	4	5	6	7	
Damage by cattle in summer 2000								
Browsing of apical shoots	7	15	0	0	0	3	0	4 ± 6[c]
Browsing of lateral shoots	10	0	7	22	23	0	6	10 ± 9
Browsing of apical + browsing of lateral shoots	17	15	7	22	23	3	6	13 ± 8
Total other damage[a]	9	15	9	33	15	18	6	15 ± 9
Trampling	3	5	0	0	0	9	0	2 ± 4
Breaking lateral shoots	3	5	9	22	0	9	0	7 ± 8
Fraying	3	5	0	11	15	0	6	6 ± 6
Damage by wild ungulates in winter 2000/2001								
Browsing of apical shoots	3	0	0	n.d.[b]	n.d.	15	n.d.	5 ± 7
Browsing of lateral shoots	33	20	21	n.d.	n.d.	27	n.d.	25 ± 6
Total other damage[a]	3	0	0	n.d.	n.d.	3	n.d.	2 ± 2

[a]Fraying, trampling, breaking of lateral shoots.
[b]n.d. – not determined.
[c]Mean value ± standard deviation.

Factors associated with tree damage by cattle

The sum of browsed and otherwise damaged trees was linearly correlated with the cattle stocking rate, as described here by the term 'livestock units per hectare'. More than 95% of the variance in browsing frequency was explained by the linear regression with the logarithm of cattle stocking rate (Figure 1). The relationship of damage other than browsing with the stocking rate was best explained by a linear regression.

Discussion and conclusions

The percentage of trees damaged by cattle due to browsing, fraying, trampling and breaking was strongly correlated with the cattle stocking rate. On average, 4% of the sample trees were browsed by cattle. This falls below the threshold level of 12% browsed apical shoots given by Eiberle and Nigg (1987), and goes in line with the results of Liss (1988) and Huntsinger (1996), who also found low browsing rates by cattle on wood pastures. In our study, only one sample tree was browsed on both, lateral and apical shoots. Thus, browsing was not concentrated on particular trees and the trees did not loose much biomass due to browsing. Consequently, none of the sample trees in our study was browsed so intensively that tree vitality was severely affected. Extrapolating the apical shoot browsing frequency of 4% means that each young tree might be browsed by grazing cattle once every 25 years. Thus, a young tree might be browsed by cattle at most twice in its life, before reaching a height where there is no browsing

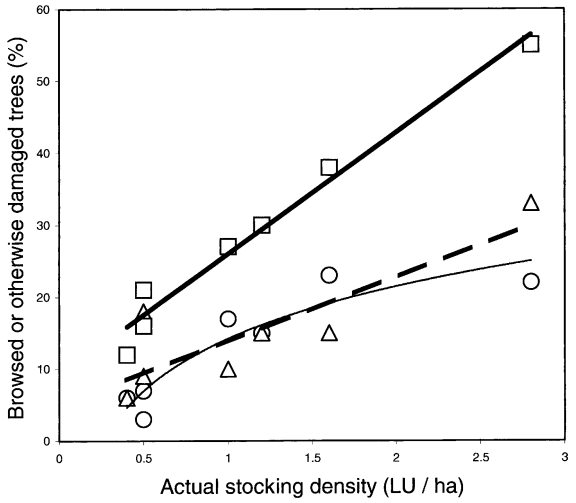

Figure 1. Actual and predicted relationships between cattle stocking rate (livestock units/ha; x) and percentage of browsed trees, otherwise damaged trees and the sum of browsed and otherwise damaged trees (y) in the cattle grazing period in summer 2000. ○, Browsed trees (%); the thin solid line shows the logarithmic regression $y = 10.463 \ln(x) + 14.213$; $R^2 = 0.869$; △, otherwise damaged trees (%); the broken line shows the linear regression $y = 8.987x + 4.872$; $R^2 = 0.741$; □, sum of browsed and otherwise damaged trees (%); the bold solid line shows the linear regression $y = 16.908x + 9.1049$; $R^2 = 0.972$.

possible anymore. In line with this, in Bavarian mixed forest stands, cattle have been found to avoid browsing on young spruces and firs (Liss 1988). In our study, browsing frequency by cattle was logarithmically correlated with the cattle stocking rate. Cattle grazing at low stocking rates is not likely to retard the regeneration of subalpine forests, which is supported by the results of Liss (1988) in grazed montane forests. Charles and Troxler (1989) recommended stocking rates from 0.5 to 1 LU ha^{-1} when no rotational grazing system is applied. In the present study, the threshold value of 12% apical shoot browsing on Norway spruce given by Eiberle and Nigg (1987) was exceeded on Range 2 only, which was grazed at a stocking rate of 1.2 LU ha^{-1}. On Ranges 4 and 5, which were grazed at stocking rates of 2.8 and 1.6 LU ha^{-1}, no apical shoot browsing but intensive lateral shoot browsing (22 and 23%, respectively) was found. None of the four ranges, grazed at stocking rates ≤ 1 LU ha^{-1}, exceeded the threshold value by Eiberle and Nigg (1987) and the maximum lateral shoot browsing was 10%. Based on these findings, we recommend cattle stocking rates not exceeding 1 LU ha^{-1}.

The correlation of cattle stocking rate and damage other than browsing, such as fraying, trampling and breaking of lateral shoots, was explained best by a polynomial regression. This suggests that higher cattle stocking rates may increase the risk of unintentional trampling on trees. The lack of a significant correlation between frequency of browsing and other damage highlights the obvious difference in causal mechanisms for browsing and other forms of damage. Fraying scars on young trees were rarely found. On average, broken lateral shoots were found on 3% of the sample trees. It is likely that the cattle cause this damage when they scratch their head on young trees. Liss (1988) noted that cattle grazing on wood pastures mainly damage young trees by trampling. In the present study, trampling damage did not occur often and was lethal in one tree only. This suggests that cattle deliberately avoid trampling on young trees >0.3 m. However, further experiments with randomly distributed planted trees are required in order to analyse trampling damage patterns caused by cattle.

In the present study, the percentage of sample trees browsed by wild ungulates during winter, as assessed on four of the ranges, was nearly 3 times that of trees browsed by cattle during the growing season. This goes in line with Liss (1988), who found that tree browsing by wild ungulates during winter surpassed browsing by cattle during the growing season in Bavarian montane forests. Also Huntsinger (1996) found much higher browsing rates by red deer than by cattle. The young trees on Range 1 were browsed by wild ungulates most intensely, due to the fact that this area – providing several feeding stations is – known to host large groups of red deer during winter. On Range 3, the browsing during the cold season derives mainly from the chamois passing the winter in the area below treeline (Silvio Sprecher, personal communication). As the assessment of the browsing frequency by wild ungulates included not only the winter period, but the relatively long period from late autumn to early spring, the young trees were not protected from browsing by the snow cover during the whole period. However, in the present study, even the sum of apical shoot browsing by wild ungulates in winter and by cattle during the growing season did not reach the threshold level given by Eiberle and Nigg (1987) to ensure the regeneration of Norway spruce in montane forests.

Taking into account that on the one hand subalpine wood pastures provide herbage of sufficient digestibility even for lactating cows (Mayer et al. 2003), and that on the other hand detrimental effects on young trees can be avoided if cattle stocking rates do not exceed 1 LU ha^{-1}, forest grazing in subalpine zones comparable to the area investigated can be recommended as a reasonable land use form.

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