Short communication:

Forest pasturing of livestock in Norway: effects on spruce regeneration

Olav Hjeljord[1], Trond Histøl[2], and Hilde Karine Wam[2*]

[1] *Norwegian University of Life Sciences, Department of Ecology and Natural Resource Management, Box 5003, 1432 Ås, Norway.*

[2] *Norwegian Institute for Agricultural and Environmental Research, Organic Food and Farming Division, Gunnarsveg 6, 6630 Tingvoll, Norway.*

**Author of correspondence: email hilde.wam@bioforsk.no, phone +47 920 10 746*

First author bio: male, born 1941, professor in wildlife ecology

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Abstract

Forest pasturing of free-roaming livestock is a common practice in many parts of the world, but knowledge on how it affects tree regeneration in boreal forests is lacking. We mapped tree density, livestock site use and accumulated damage to young trees of commercial interest (Norway spruce, *Picea abies* L. Karst.) on 56 clearcuts inside and outside a fenced forest area used for livestock pasturing in Ringsaker, Norway. Inside the fence 56 ±1.8 % of spruce trees were damaged compared to 37 ± 3.4 % outside. Proportion of damaged spruce trees was positively related to cattle use of the clearcut, but not so for sheep. On the most intensively used clearcuts, four out of five trees were damaged. The density of deciduous trees overall was five times lower inside compared to the outside of the fence (depending on plant species). While livestock grazing may reduce plant competition in favour of spruce, the current animal density clearly is impeding forest regeneration in the study area.

Key words: Browsing, cattle, damage, timber, sheep, ungulate

Introduction

Forest pasturing of free-roaming livestock is extensive in many parts of the world, with various level of success concerning integration with other stakeholder interests (Asner et al. 2004). In Norway, the tradition dates back at least 5 000 years (Hjelle et al. 2006), and the associated easements are deeply rooted in Norwegian customary practice. However, as commercial forces encourage intensified agricultural production (Pender 1998), conflicts with other stakeholders are increasing.

In Norway, the number of animal farms has dropped from 150 000 to 30 000 in 50 years, and continues to decline at a steady rate of about 4% per year (Statistics Norway 2012a). While the load of forest pasturing is going down at the national level (Austrheim et al. 2008), it is locally intensified. The remaining farms keep increasingly larger herds, and the average herd size of sheep and cattle on Norwegian farms currently is five times what it was 50 years ago. Furthermore, there is an ongoing shift from sheep and dairy cows to heavier breeds of beef cattle (Statistics Norway 2012b). The latter, such as Charolaise and Simmental, weigh up to 30% more than the Norwegian Red (Mason 1996). Beef cattle are also kept in a manner that more strongly enforces social cohesion, for example by herd keeping and letting calves suckle. This change in herd structure is expected to make grazing more concentrated (Arnold and Dudzinski 1978; Sowell et al. 1999).

It is well established that livestock grazing reduces regrowth of herbaceous and deciduous plants after forest clearing (Östlund et al. 1997; Belsky and Blumenthal 1997). In the perspective of commercial forestry this is considered positive because it reduces competition for nutrients, water and light (Zimmerman and Neuenschwander 1984; Prolux and Mazumder 1998). However, if the load of livestock becomes too high, their grazing, trampling and bedding may lead to erosion, soil packing and tree damage (Fleischner 1994; Hester et al. 2000). Like for all exploitation of natural resources, forest pasturing should be sustainable, i.e. animal numbers must balance other forest ecosystem services, also in a long term perspective.

While many studies have addressed the sustainability of livestock grazing in tropical and temperate forests (see Rook et al. 2004 for a review), studies are almost completely lacking for the boreal forests of the northern hemisphere. In Scandinavia, the few studies there is also have limited data and the publications are not readily available (e.g., Bjor and Graffer 1963). This knowledge gap needs to be filled in order to regulate the grazing intensity in a sustainable manner.

In this study we mapped tree density, livestock site use and accumulated damage to young trees of commercial interest (Norway spruce, *Picea abies* L. Karst.) on 56 clearcuts inside and outside an area of livestock grazing in Ringsaker, Norway. A fenceline crosses the terrain irrespectively of vegetation type, soil fertility, topography and forestry practice, thereby creating a valuable experimental setting. We hypothesized that 1) tree recruitment would be lower and 2) damage levels would be higher inside the fence compared to outside, and 3) damage levels would be positively related to livestock site use.

Methods

Study area

The Ringsaker Common Lands is situated in the county of Hedmark in southeastern Norway (UTM 278860'E, 6765400'N). The study area is located on the lower (200-400 m.a.s.) west-facing slopes of the major river valley Mjøsa-Glomma. The climate is continental with cold winters (average temperature in February is -8°C) and warm summers (average temperature in July is 15°C). Average yearly precipitation is 590 mm, with highest levels in July and August. Snow generally stays on the ground from late October until mid April.

The forest is typical of the boreal coniferous zone of western Norway with spruce as the dominating tree species (Påhlsson 1984), with intermittent mixes of Scots pine *(Pinus sylvestris* L.) and deciduous trees (see result section). The field layer is species poor compared to adjacent regions, with a dominance of bilberry (*Vaccinum myrtillus* L.) in older forest and grasses (mainly wavy hair grass *Deschampsia flexuosa* L. and *Calamagrostis* spp.) on clearcuts (Fig. 1). In the intermediate growth stages, most vascular plants disappear due to the dense spruce causing sparce light to reach the forest floor. The forests of the area are subject to intensive commercial forestry, with practically all logging carried out as clearcutting of 80-100 year old stands. Clearcuts are generally in the range of one to three ha and almost exclusively regenerated by planting.

The study area has a long tradition of forest pasturing of livestock. Approximately 50 000 ha is fenced off into one continuous rangeland area, of which 25 000 ha is productive forest and an additional 10 000 ha mountain range. The number of sheep (*Ovis aries* L., sows and lambs has remained stabile at about 15 000 animals (0.6 ha^{-1} of forest land) during the last two decades. The number of cattle (*Bos taurus* L.) has increased from a historical low of 500 animals in 1995 (0.02 ha^{-1}) to a current 1800 (0.08 ha^{-1}). In 1995 all the cattle were of dairy breeds (mainly heifers and barren cows of the Norwegian Red Cattle), and in 2012 approximately 75% of the cattle were of various imported beef breeds. The grazing season runs from medio June to medio September. The presence of wild ungulates (mainly moose *Alces alces* L., and some roe deer *Capreolus capreolus* L.) is negligible inside the livestock fence in summer (1 moose faeces/daa versus 38 for cattle, this study), but more prevalent outside the fence (6 moose faces/daa).

Data Collection

The study was conducted in September 2012. By doing the survey in late summer we covered the complete pasturing season, which runs from June to September. Sites to be surveyed were selected across all the forested area inside the livestock fence as well as in adjacent areas outside the fence. All sites consisted of younger clearcuts (development class II, i.e. 5-15 years since cutting, mean tree height up to 10-12 m, Tomter 1999) on similar soil fertility (G14 and G17, Tveite 1977). Apart from planting, the study sites had not been subject to silviculture treatment, such as brush control or soil scarification. A list of all available study sites was obtained from the data bases of the regional forest owners' association Mjøsen Skog SA.

Because we wanted to estimate the average level of forest damage, but also be able to relate the level of forest damage to the level of livestock use, we selected sites to be surveyed in two ways: 1) a randomized sample drawn from all available sites; and 2) a targeted sample, representing the largest possible gradient in livestock use. These sites were selected by the local managers based on the guideline that low livestock use is indicated by <10% replanting (i.e. replacing a previously planted sapling that has died or disappeared), and high livestock use is indicated by >50% replanting. Sites outside the fence (no livestock) were used as controls. The study design was thus balanced on three site types: random inside, targeted inside and random outside, aiming for at least 15 of each.

At each sampling site we laid out 2-m wide transects forming a triangle, with the corners placed one third of the clearcut width in from the edge. The length of the transect triangles therefore varied with clearcut size. On average we walked 234 ± 32 m per site (covering 468 m^2). Along each transect we recorded: **1) tree density**, i.e. the number of tree saplings. All trees >30cm tree height were counted, and recorded to species. Lower saplings are covered in the field vegetation, and therefore seldom intentionally browsed (Wam et al. 2010); **2) livestock site use**, as indexed by counting faeces along the transect (Bennett et al. 1940); and **3) forest damage**, defined as the proportion of spruce trees that showed sign of damage. We did not distinguish between age, types or causes of damage. Because sites were selected to be similar outside and inside the fence (apart from the presence of livestock), we attribute differences in the damage level to livestock activity. We defined damage as a) broken leader shoot/main stem; b) wounds in the bark, roots or inner structures; c) crown deviations (lost, dead or dying parts); or d) tree axis tilted >25% from perpendicular to the base.

Data Analyses

We analyzed differences between sites with ordinary *t*-tests as all parameters were normally distributed. In the reported t_n statistics (two-sided), n is the number of non-zero observations minus the number of groups. We used linear regression to check for correlative relationships between livestock use and the proportion of damaged spruce trees on a clearcut. Three extreme outliers in parameters pertaining to tree density were omitted from part of the analyses; one stemming from a clearcut with delayed planting (the site had only 17 spruce trees/daa), and two stemming from clearcuts with unusually high number of spruce trees (425 and 568 trees/daa). The statistical analyses were run in MINITAB statistical software (release 15.1.1.0, MINITAB Inc. 2007). All central measures are given as mean ± SE if not otherwise indicated.

Results

Inside the fence, none of the parameters of interest differed between the random sites and the targeted sites, which were selected by the managers (cattle density t_{37}= -0.1, P = 0.894; sheep density t_{37}= 0.4, P = 0.721; tree density (deciduous and pine) t_{37}= 0.1, P = 0.824; spruce density t_{35}= -0.3, P = 0.792; spruce damage t_{35}= -0.6, P = 0.531). The targeted and the random sites are therefore pooled.

Tree density

There was a strong tendency of lower spruce density inside the fence (t_{52}= -1.8, P = 0.093), compared to the outside. The density of other trees (deciduous species and pine) was significantly lower inside the fence compared to outside (t_{52}= -4.8, $P \leq 0.001$). Overall the ratio was approximately 1: 5 (47 ± 11 trees inside versus 259 ± 52 outside), but this varied with species (Fig. 2). For rowan (*Sorbus aucuparia*, L.), for example, it was more than 1: 15. Most of the deciduous trees were patchily distributed, i.e. found predominantly on a few study sites.

Livestock site use

We found livestock faeces on 39 out of 40 sites inside the fence. There were 380 ± 62 faeces per ha from cattle and 295 ± 54 faeces per ha from sheep. As expected, we found no livestock faeces outside the fence.

Forest damage

There was substantially more damage to young spruce trees inside the fence compared to the outside (t_{54}= 5.2, $P \leq 0.001$) (Fig. 3). Outside the fence the percentage of damaged trees ranged from 9 to 51 %, versus from 33 to 82 % inside the fence. Damage levels were positively related to cattle use of the clearcut (density of faeces) (R^2 = 29.3, df = 34, $P \leq 0.001$) (Fig. 4), but not so for sheep (R^2 = 6.2, df = 34, P = 0.144).

Discussion

Livestock grazing clearly was hindering forest regeneration in Ringsaker. The number of young spruce trees was reduced by at least 22% (not adjusting for the fact that supplemental planting has been more prevalent inside the fence than outside, T. Uggen, pers. comm.). Furthermore, compared to the control area with no livestock, the proportion of damaged spruce trees was 1.6 times higher inside the fence. On the most affected sites inside the fence, four out of five spruce trees were damaged. Because the survey sites inside and outside the fence were selected to be otherwise similar, we can attribute the difference in damage levels (21%) to livestock activity.

Cattle site use was related to level of spruce damage. Albeit significant, the fit was not very strong. Sites with much damage were found at varying site use, but heavy site use was always associated with high damage levels. This pattern may be an effect of intensively used sites becoming progressively less favourable over the course of years. The cattle move on, but the damage remains. Because using pellet counts as a proxy for animal activity is influenced by defecation- and decomposition rates (Neff 1968; Putman 1984), our data should not be directly extrapolated to other areas. Preferentially, therefore, future studies of livestock use of forests should include remote sensing of animal movement.

Our study suggests that high levels of tree damage from pasturing livestock in spruce forest can occur at lower animal densities than previously held. We are aware of only two comparable studies in spruce forest that have been published (see also Liss 1988). In the Swiss Alps, with 0.4- 2.8 livestock units of cattle (600 kg body weight) (LU) per ha, 12-55% of spruce trees were damaged by the animals after one summer, but none fatally (Mayer et al. 2006). In a series of studies in the 1950s in Norway, 14% of spruce saplings were destroyed by livestock after 6 summers of grazing (up to 3.8 LU/ha), and of the surviving saplings 26% had livestock-related damages (Bjor and Graffer 1963). The livestock density in our study was <0.2 LU/ha, and the grazing period averaged 7 years. We attribute at least 22% of lost spruce saplings, and 21% of damaged spruce trees, to livestock activity.

While spruce is the only tree of interest for commercial forestry in the Ringsaker area, deciduous trees (and pine) are important for other stakeholders (e.g., game providers and non-consumptive interests. It should be noted that rowan and *Salix* spp. were practically non-existent inside the fence.

Implications

The Ringsaker study illustrates an important call to managers: As natural resources are becoming increasingly scarce, and the commercial exploitation of them more specialized, single-purpose management is no longer sufficient. Density of livestock and logging potential must be determined by an adaptive approach coupling not only economic, but also ecological and social aspects (e.g., Brunson 2012; Bestelmeyer and Briske 2012; Wam et al. 2012).

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Fig. 1. Clearcuts in Ringsaker, Norway, are species poor, with planted spruce and a dominance of grasses (mainly *Deschampsia* spp. and *Calamagrostis* spp.).

Fig. 2. Tree density (tree height 30-300 cm) on clearcuts (5-15 years since cutting, soil fertility G14-G17), inside and outside a fence delimiting forest grazing of livestock (approximately 30 sheep and 4 cattle per km2) in Ringsaker, Norway 2012.

Fig. 3. Damage levels on young spruce trees (tree height 30-300 cm) on clearcuts (5-15 years since cutting, soil fertility G14-G17), inside and outside a fence delimiting forest grazing of livestock (approximately 30 sheep and 4 cattle per km2) in Ringsaker, Norway 2012.

Fig. 4. Damage on young spruce trees (tree height 30-300 cm) in relation to a) cattle and b) sheep use of clearcuts (forest age 5-15 years, soil fertility G14-G17), Ringsaker, Norway 2012.

Fig. 1

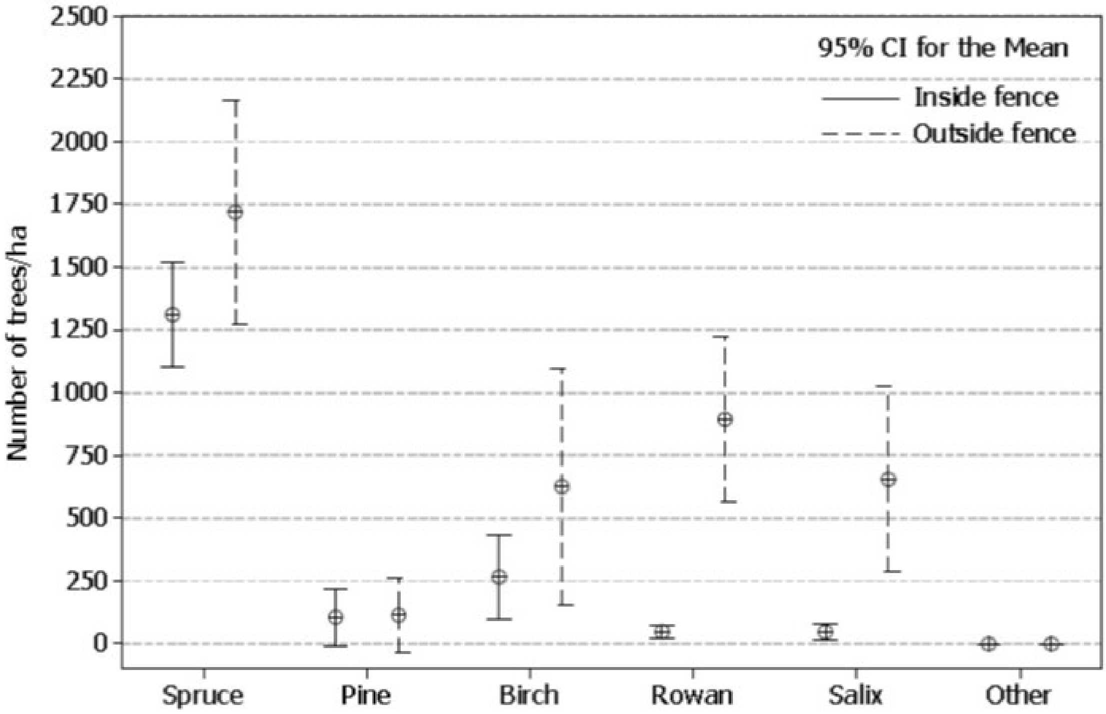
95% CI for the Mean
Inside fence
Outside fence
Number of trees/ha
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
Spruce
Pine
Birch
Rowan
Salix
Other

Fig. 2

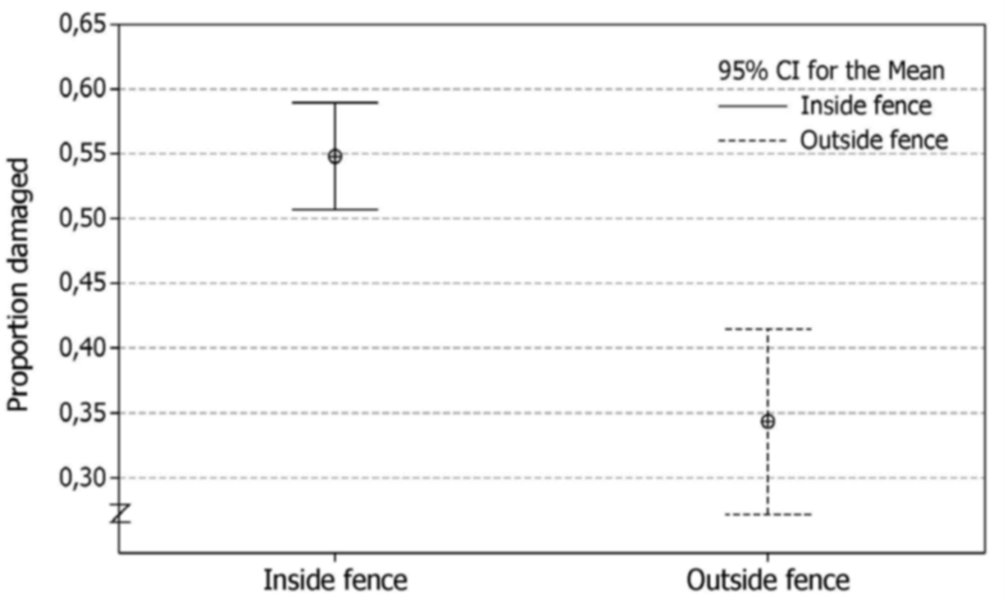
95% CI for the Mean
Inside fence
Outside fence
Proportion damaged
0,65
0,60
0,55
0,50
0,45
0,40
0,35
0,30
Inside fence
Outside fence

Fig. 3

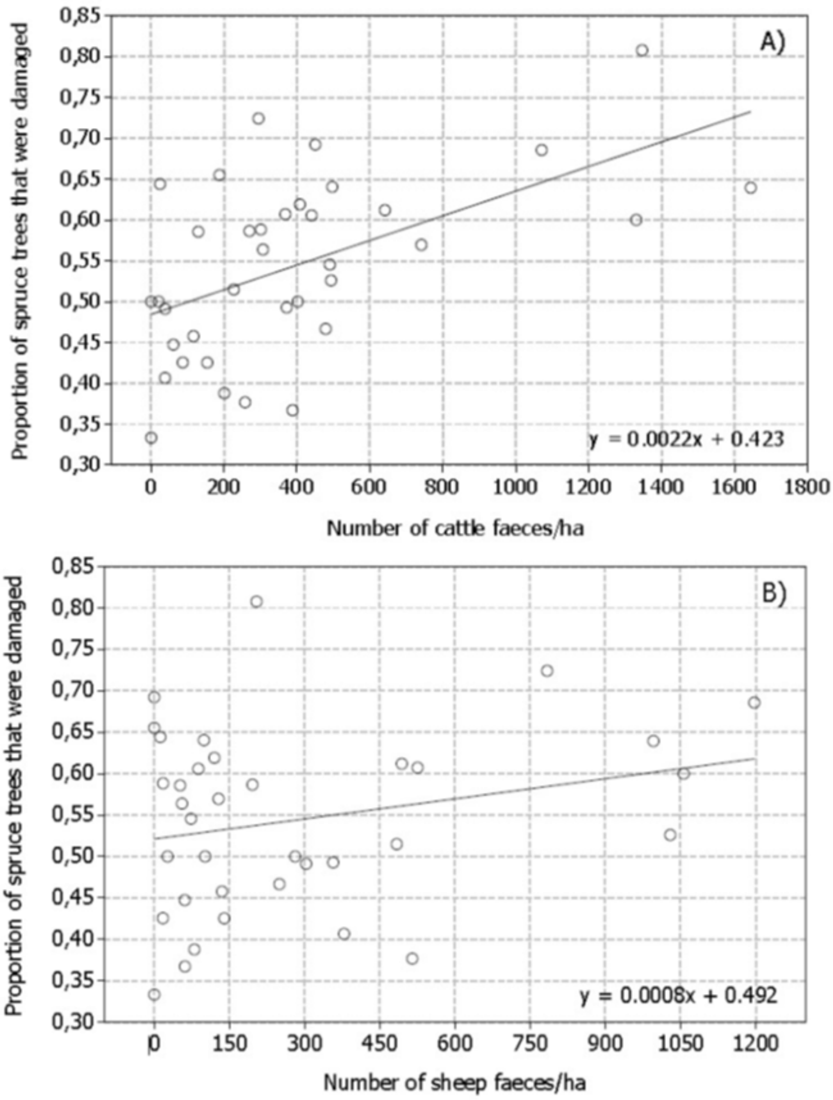
A)
Proportion of spruce trees that were damaged
0,85
0,80
0,75
0,70
0,65
0,60
0,55
0,50
0,45
0,40
0,35
0,30
y = 0.0022x + 0.423
0 200 400 600 800 1000 1200 1400 1600 1800
Number of cattle faeces/ha
B)
Proportion of spruce trees that were damaged
0,85
0,80
0,75
0,70
0,65
0,60
0,55
0,50
0,45
0,40
0,35
0,30
y = 0.0008x + 0.492
0 150 300 450 600 750 900 1050 1200
Number of sheep faeces/ha

Fig. 4