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Lodgepole pine nutrition and growth on grazed forest cutblocks in southern British Columbia

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Abstract

Forest grazing occurs on replanted or naturally regenerated cutblocks, giving temporary grazing opportunities for British Columbia's beef industry. However, grazing on forest cutblocks sometimes results in conflicts between the different interests of the timber and ranching industries. The forester's primary concern about cattle grazing and forage seeding on cutblocks is tree damage by trampling and browsing, followed by soil compaction and altered tree nutrition. This study evaluated the effect of long-term cattle grazing and forage seeding on growth and nutrition of lodgepole pine on three grazed forest cutblocks near Kamloops and Merritt, B.C.

Grazing regimes consisted of ungrazed exclosures and pastures grazed at 50% forage utilization during 1989–1998. Forage seeding treatments were 0 and 12 kg/ha. Tree measurements and foliage samples were obtained in September 1999. Tree height, current-year growth (length of leader internode), and foliar nutrient levels of regenerating lodgepole pine have not been significantly affected by forage seeding rate and 9 years of cattle grazing. The absence of significant effects on tree growth and nutrition is particularly noteworthy because of the marginal or somewhat deficient status of several nutrients (N, P, B, Fe, and Cu) on these study sites.

The management implications of this study relate to the benign effects of 9 years of cattle grazing on lodgepole pine nutrition and growth. The study provides evidence that cattle grazing is compatible with forestry. These results support the integrated use of forested rangelands in southern British Columbia. Attempting to extrapolate these findings to other site conditions should be done with caution.

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Introduction

Forest grazing in British Columbia often occurs on replanted or naturally regenerated cutblocks. These areas provide temporary grazing opportunities for the provincial beef industry until tree canopy closure reduces forage production. In southern British Columbia, Crown range accounts for about 85% of the area used for grazing, of which nearly 80% occurs on forest land (Wikeem *et al.* 1993). Grazing on cutblocks is sometimes accompanied by conflicts between interests of the timber and livestock industries. In particular, cattle grazing on cutblocks raises concerns relating to possible reduction of tree seedling stocking and growth rates resulting from trampling and browsing (Newman and Powell 1997) as well as soil compaction (Wood *et al.* 1989).

Grazing may also benefit forest regeneration by altering nutrient cycling and reducing competition from native vegetation (McLean and Clark 1980). Accordingly, measurements of key nutrients may be useful indicators of change on forest cutblocks used for timber production and cattle grazing. This type of information is lacking, even though clearcuts have become an important type of summer range in the British Columbia Interior. The only outline addressing nutrient cycling (i.e., nitrogen gains and losses) on grazed cutblocks is the literature review by Thompson *et al.* (2000). Estimates of nitrogen losses (in cattle tissue plus volatilization) due to cattle grazing were 2.4 kg/ha per year on seeded and 0.8 kg/ha per year on unseeded cutblocks. These estimates were calculated using forage yields and cattle gains summary data from a long-term forest grazing experiment in the British Columbia Interior, as well as many assumptions.

Our study determined whether the combination of seeding clearcuts with domestic forage species and grazing by cattle compromises the nutrition of planted trees. The objective of this study was to determine effects of forage seeding and long-term cattle grazing on growth and nutrition of lodgepole pine on cutblocks in southern British Columbia.

Materials and Methods

Site Description

The study is replicated at three cutblocks originally established for a large-scale forest grazing study (Wikeem *et al.* 1991) in the Very Dry Cool Montane Spruce biogeoclimatic subzone (MSxk) consisting mostly of site series 01 and 07. The average site index for the cutblocks is 19. Two cutblocks are located near Tunkwa Lake (50 km SW of Kamloops, B.C.: 50°33'N, 120°56'W) and one near Helmer Lake (30 km NE of Merritt, B.C.: 50°21'N, 120°37'W). Elevation and slopes of the three cutblocks are similar, averaging 1400 m and 10–15%, respectively.

The soils are predominantly Melanic Brunisols, with Luvisols occurring in moister areas. Parent material is predominantly glacial till. Soil texture at 0–7.5 cm depth is sandy loam for Tunkwa Lake cutblock 1 and loam for Tunkwa Lake cutblock 2 and Helmer Lake (Krzic *et al.* 1999). Average contents of coarse fragments (diameter >2 mm) are 14, 20, and 22% (volume) on Tunkwa Lake cutblock 1, Tunkwa Lake cutblock 2, and Helmer Lake cutblock, respectively. Average organic matter contents at the 0–7.5 cm depth of the mineral soil are 19.1 t/ha for Tunkwa Lake cutblock 1, 21.5 t/ha for Tunkwa Lake cutblock 2, and 21.3 t/ha for the Helmer Lake cutblock. According to the Forest Practices Code of British Columbia, these soils were identified to have a moderate to high hazard rating for soil compaction and puddling (B.C. Ministry of Forests 1999).

The findings of this study could help land managers develop plans focused on mortality of lodgepole pine seedlings due to cattle trampling.

The Tunkwa Lake cutblocks were harvested and windrowed in the fall of 1986, burned, and then drag-scarified to achieve 25% mineral soil disturbance in the fall of 1987. Most of the Helmer Lake cutblock was harvested in 1985. An additional 10 ha was harvested in fall 1987 when the whole site was rough-piled, track-and-blade-scarified, and burned. The cutblocks were aerially seeded in May 1988 with a standard regional forage mix at the time which included, by weight, 35% orchardgrass (*Dactylis glomerata* L.), 5% timothy (*Phleum pratense* L.), 40% alsike clover (*Trifolium hybridum* L.), and 20% white Dutch clover (*Trifolium repens* L.). Seeding rates were 0 and 12 kg/ha. Immediately after forage seeding, 1-year-old nursery-grown lodgepole pine seedlings were planted on all three cutblocks at a density of 1400 stems per hectare (2.7-m spacing). In June 1988, each seeding treatment was fenced in half to produce four, 5-ha pastures for grazing, with the longitudinal axis perpendicular to the slope. A 0.5-ha exclosure was constructed in the middle of each seeding treatment to provide an ungrazed control. Grazing occurred from mid-July to mid-August from 1989 to 1998. Cow–calf pairs were used to achieve 50% use of available forage in each pasture. Cattle numbers were modified depending on forage availability in each year. For example, a seeded pasture may be stocked with 10 cow–calf pairs for 30 days, while an unseeded pasture may be stocked with 5 cow–calf pairs for the same period. This resulted in stocking rates averaging 0.6 and 1.5 animal unit month (AUM)/ha for the unseeded and seeded treatments, respectively.

Pinegrass (*Calamagrostis rubescens* Buckl.) and sedges (*Carex* spp.) were the most dominant native grass or grasslike species, while fireweed (*Epilobium angustifolium* L.) and wild strawberry (*Fragaria virginiana* Duchesne) were the most common forbs on unseeded treatments of these cutblocks. The broad-leaved native forb composition of seeded pastures was similar, but much of the pinegrass was replaced by timothy, orchardgrass, and white clover. In regard to N-fixing species, arctic lupine (*Lupinus arcticus* S. Wats.) was present only on the Helmer Lake cutblock, Sitka alder (*Alnus crispa* [Ait.] Pursh) was present only on the Tunkwa Lake cutblocks, and white Dutch clover was present on all three cutblocks.

Sampling and Analyses

Tree height and current-year growth (length of leader internode) measurements, and foliage sampling were done on September 22–23, 1999, (i.e., during dormancy) on the ungrazed exclosure and cutblocks grazed to achieve 50% forage utilization on both seeded and unseeded pastures. Four transects were randomly selected on each treatment plot and three measurements or samples were taken per transect. A total of 144 foliage samples were collected (3 cutblocks × 2 grazing treatments × 2 forage seeding treatments × 4 transects × 3 samples per transect). Trees chosen for sampling or measurement were randomly selected along the transects provided that the chosen tree was not deformed by western gall rust (*Endocronartium harknessii*). In total, three trees were discarded using this rule. Unpublished data from the sites showed no correlation between cattle use and incidence of western gall rust. Possibly, some of the selected trees were not planted stock because natural regeneration of lodgepole pine occurred on all cutblocks. It is assumed that all treatments had the same amount of natural regeneration and therefore the same potential for selection of naturally regenerated trees. Tree height was measured up to the terminal bud and also to the last whorl. The difference between the total tree height and height to last whorl represents current year's height growth. Foliage samples were collected from four branches from the third and fourth whorl below the leader (Ballard and Carter 1986). Samples taken on the same tree were composited before analysis. Only the current-year foliage was sampled.

Foliage samples were dried for 48 hours at 70°C and analyzed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), boron (B), and aluminum (Al). The concentrations of all these elements, except N, were determined on an inductively coupled argon plasma (ICP) unit after being digested in a closed microwave digestion vessel (under high pressure) using 70% nitric acid, 37% hydrochloric acid, and 30% hydrogen peroxide (Kalra and Maynard 1991). After being digested, foliar N concentration was determined on an automated combustion analyzer (Carlo Erba, Milan, Italy) by the Parkinson and Allen (1975) procedure involving concentrated sulphuric acid, lithium sulfate, and hydrogen peroxide.

Statistical Analyses

Tree measurements and foliage nutrient content data were analyzed in a split-plot randomized, complete block design, with three replications (blocks) and four observations per experimental unit. The forage seeding rate was the main treatment, with grazing as the sub-treatment. Analysis of variance (ANOVA) was carried out using the SAS general linear model procedure (SAS Institute Inc. 1989).

Post-hoc power analyses were conducted to determine if the experiment had sufficient power to detect biologically significant treatment differences of 33% (Nemec 1991). When an *F*-test for a treatment effect has a high *P*-value (i.e., the *F*-test is non-significant), then there is little evidence for rejection of the null hypothesis of no treatment differences. Under those circumstances, the ability or power of the *F*-test to find differences between treatment responses should be checked. If the power is high, then accepting the null hypothesis is reasonable; if the power is low, a clear decision cannot be made.

Results and Discussion

Tree Nutrition

Based on our unpublished data from lodgepole pine stands in the British Columbia Interior over the past 20 years, the foliar N data (1.2–1.3% N) of Table 1 appear typical for the region. In addition, these levels suggest that N is somewhat deficient in the trees on our study sites. Based on data collected by Swan (1972), the pine also seems somewhat low in P, at concentrations of 0.13–0.14%, while concentrations of K, Ca, and Mg are adequate. Despite the somewhat low P concentration, N is presumably more limiting for tree growth (Ballard and Carter 1986).

Neither the forage seeding rate nor the cattle grazing treatment (nor their interaction) had a statistically significant effect on foliar macronutrient concentrations of lodgepole pine (Table 1). Post-hoc power analysis indicated that the *F*-test had enough power to detect a 33% difference in K and Mg due to the forage seeding treatment had this difference existed (Table 2). Power was also sufficient to detect a 33% difference in N, P, K, Ca, Mg, and S due to the grazing treatment (Table 2). The *F*-test did not have sufficient power to detect differences in N, P, Ca, and S due to the forage seeding (Table 2). The absence of a significant treatment effect on N is of particular interest because of the N-balance implications of forage seeding and cattle grazing on forest cutblocks (Thompson *et al.* 2000).

The forage seeding and cattle grazing treatments did not significantly affect lodgepole pine foliar micronutrient and Al concentrations (Table 3). Post-hoc power analysis indicated that the *F*-test had enough power to detect a 33% difference in Fe, Zn, Mn, and B due to the grazing treatment, while there was not enough power to detect differences in Al and Cu (Table 2). The *F*-test did not have a sufficient power to detect differences in Fe, Cu, Zn, Mn, B, and Al due to the forage seeding treatment (Table 2).

Observed Zn and Mn concentrations appear to be at adequate levels (Table 3). The lodgepole pine in this study may be near the threshold of deficiency with foliage B concentrations ranging from 14 to 17 ppm. In greenhouse work with lodgepole pine, Majid (1984) found that the critical B deficiency threshold ranged from 7 to 16 ppm. Boron deficiency, indicated by low foliar B levels, visual symptoms such as top dieback, and response to B-containing fertilizers, has been observed

TABLE 1. Percentage of plant macronutrients at two forage seeding rates on two cattle grazing treatments with *P* values (*P* = probability of rejecting null hypothesis when it is true)

Forage seeding rate (kg/ha)	Grazing treatment	N	P	K	Ca	Mg	S
0	Ungrazed	1.21	0.13	0.60	0.17	0.10	0.07
		(0.02)[a]	*(0.002)*	*(0.01)*	*(0.005)*	*(0.002)*	*(0.001)*
	Grazed	1.21	0.13	0.59	0.17	0.10	0.07
		(0.02)	*(0.001)*	*(0.01)*	*(0.004)*	*(0.002)*	*(0.001)*
12	Ungrazed	1.23	0.14	0.58	0.18	0.10	0.08
		(0.02)	*(0.002)*	*(0.01)*	*(0.005)*	*(0.002)*	*(0.001)*
	Grazed	1.26	0.14	0.61	0.17	0.10	0.08
		(0.02)	*(0.003)*	*(0.02)*	*(0.004)*	*(0.002)*	*(0.001)*
Source of variation	*df*						
Block (B)	2	0.0001	0.0004	0.0001	0.0001	0.4785	0.0001
Seeding rate (SR)	1	0.3015	0.6609	0.8429	0.7326	0.9192	0.5905
Error(a)	2	–	–	–	–	–	–
Grazing (G)	1	0.3115	0.6762	0.5891	0.7319	0.5639	0.1449
SR × G	2	0.2976	0.2792	0.2514	0.5046	0.7254	0.7946
Error(b)	4	–	–	–	–	–	–

[a] Standard error of the mean in parentheses (*n* = 36; i.e., three sites, four transects, and three samples per transect).

in the interior lodgepole pine stands in some areas (Brockley 1990). Majid (1984) suggested that 44 ppm of total Fe was approximately the deficiency threshold for lodgepole pine grown under greenhouse conditions.

TABLE 2. Power of the *F*-test for hypothesized difference of 33% from control, calculated for forage seeding rate and grazing treatments

Nutrient	Power of *F*-test for forage seeding	Power of *F*-test for grazing
N	0.47	1.00
P	0.46	1.00
K	0.99	1.00
Ca	0.59	1.00
Mg	0.99	1.00
S	0.57	1.00
Fe	0.19	0.99
Cu	0.20	0.16
Zn	0.21	0.93
Mn	0.07	0.99
B	0.08	1.00
Al	0.06	0.47

Thus, the total Fe concentrations observed in this study, ranging from 37 to 39 ppm, may represent a deficiency or near-deficiency situation. Copper concentrations of 3.3–3.9 ppm may be slightly deficient, since Majid and Ballard (1990) suggested 4 ppm as the deficiency threshold for Cu in lodgepole pine.

The low levels of N, S, Fe, and Cu may reflect the fire history of the area and the burn carried out after logging. Nitrogen and sulphur tend to be lost by volatilization during combustion, while the high pH associated with ash at the soil surface may be responsible for lower solubility and hence low availability of Fe and Cu after fire (Brockley *et al.* 1992).

Tree Growth

Tree heights integrate the height growth rates over the past life of the trees, whereas leader lengths indicate current height growth rates. Comparisons of both total heights and leader lengths can be useful for indicating whether early growth superiority of a particular treatment is currently being sustained or reversed. Neither total heights nor leader lengths were significantly affected by forage seeding rate and grazing treatments (Tables 4 and 5). Post-hoc power analysis indicated that statistical power was sufficient to detect a 33% difference

TABLE 3. Plant micronutrients and aluminum (ppm) at two forage seeding rates on two cattle grazing treatments with *P* values (*P* = probability of rejecting null hypothesis when it is true)

Forage seeding rate (kg/ha)	Grazing treatment	Fe	Cu	Zn	Mn	B	Al
0	Ungrazed	37.2	3.9	38.8	115.8	16.9	157.6
		(1.22)[a]	*(0.41)*	*(1.02)*	*(7.92)*	*(0.88)*	*(18.45)*
	Grazed	36.7	3.3	39.4	111.8	15.8	207.5
		(1.17)	*(0.10)*	*(0.74)*	*(6.88)*	*(1.32)*	*(24.08)*
12	Ungrazed	39.4	3.9	40.1	96.5	14.0	149.3
		(2.07)	*(0.38)*	*(1.08)*	*(6.43)*	*(0.70)*	*(20.90)*
	Grazed	38.5	3.6	41.8	95.7	15.1	116.5
		(1.06)	*(0.21)*	*(0.96)*	*(5.99)*	*(0.78)*	*(17.59)*
Source of variation	*df*						
Block (B)	2	0.6591	0.0023	0.0001	0.0725	0.0001	0.0002
Seeding rate (SR)	1	0.2347	0.5578	0.2408	0.5040	0.1296	0.4687
Error (a)	2	–	–	–	–	–	–
Grazing (G)	1	0.5497	0.1924	0.1351	0.8182	0.9556	0.8411
SR × G	2	0.8669	0.6597	0.4212	0.8791	0.1080	0.3595
Error (b)	4	–	–	–	–	–	–

[a] Standard error of the mean in parentheses ($n = 36$; i.e., three sites, four transects, and three samples per transect).

TABLE 4. Tree response to forage seeding and cattle grazing treatments

Forage seeding rate (kg/ha)	Grazing treatment	Leader length	Tree height
0	Ungrazed	45.6	289.6
		(2.0)[a]	*(13.8)*
	Grazed	47.6	298.7
		(1.8)	*(10.3)*
12	Ungrazed	51.5	316.1
		(2.2)	*(14.8)*
	Grazed	49.3	261.2
		(1.5)	*(12.0)*

[a] Standard error of the mean in parentheses (*n* = 36; i.e., three sites, four transects, and three samples per transect).

TABLE 5. *P*-values (*P* = probability of rejecting null hypothesis when it is true) for treatment effects on tree measurements and power of *F*-test for hypothesized difference of 33% from control

		Leader length (cm)		Tree height (cm)	
Source of variation	***df***	***P*-value**	**Power of *F*-test**	***P*-value**	**Power of *F*-test**
Block (B)	2	0.0046	–	0.0047	–
Seeding rate (SR)	1	0.4594	0.11	0.9224	0.73
Error (a)	2	–	–	–	–
Grazing (G)	1	0.9755	1.00	0.3274	0.26
SR × G	2	0.5738	–	0.1942	–
Error (b)	4	–	–	–	–

in leader length due to the grazing treatment had this difference existed (Table 5). Similarly, power was sufficient to detect a 33% difference in tree height due to the forage seeding treatment (Table 5). We can therefore be confident that no treatment differences existed for these two factors. Power was insufficient to detect differences in leader length due to forage seeding, or in tree height due to grazing (Table 5).

The absence of significant treatment effects on tree growth is consistent with the observed absence of significant treatment effects on macronutrients and on soil bulk density of the 0–7.5 cm layer documented in a study by Krzic *et al.* (1999) carried out on the same cutblocks. In addition, Krzic *et al.* (2001) showed that soil penetration resistance in grazed pastures on these same sites was higher between the 5–15 cm depth and lower between the 20–30 cm depth, when compared with ungrazed cutblock areas. Soil penetration resistance to a depth of 30 cm on grazed pastures was consistently below 2500 kPa, a commonly cited critical value for root penetration and growth (Greacen *et al.* 1969; Busscher *et al.* 1986). Although minor modification of soil structure might be associated with the grazing treatments, this was of little importance for tree growth. Soil physical changes, reported in two studies by Krzic *et al.* (1999 and 2001), may have been limited by soil strength associated with somewhat coarse soil texture, high coarse fragment content, and generally good drainage.

Results from other studies that have examined tree height response to cattle grazing have been mixed. For example, McLean and Clark (1980) reported that height of 4- to 6-year-old lodgepole pine was reduced by 6% in an unseeded pasture, and by 12% in a seeded pasture by the end of 6 years of grazing in the Engelmann Spruce–Subalpine Fir and the Interior Douglas-fir biogeo-climatic zones of the British Columbia Interior.

However, they also observed insignificant effects of grazing on pine height in some seeded and unseeded areas. Krueger and Vavra (1984) in eastern Oregon found that ponderosa pine (*Pinus ponderosa* Dougl. *ex* P.&C. Lawson), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), western larch (*Larix occidentalis* Nutt.), and western white pine (*Pinus monticola* Dougl. *ex* D. Don *in* Lamb.) grew better in an area grazed by cattle than in an ungrazed areas. After 20 years, trees in the grazed stand were 17–50% taller than in the ungrazed stand.

Conclusions

Tree height, current height growth, and foliar nutrient levels of regenerating lodgepole pine have not been significantly affected by forage seeding rate and 9 years of cattle grazing at 50% forage utilization for three cutblocks in southern British Columbia. The absence of significant effects on tree growth and nutrition is particularly noteworthy because of the marginal or somewhat deficient status of several nutrients (N, P, B, Fe, and Cu) on these study sites.

The findings of this study support the present land management prescriptions on similar sites (i.e., well-drained, coarse-textured soils) where livestock grazing and lodgepole pine silviculture occur together. Cattle grazing can be fully compatible with timely achievement of free-growing status of pine on such sites. Attempting to extrapolate these findings to other sites should be done with caution for several reasons. For example, McLean and Clark (1980) showed that, in the Interior Douglas-fir and Engelmann Spruce–Subalpine Fir biogeoclimatic zones, the degree of forage utilization and the period of time when and over which the forage was utilized were the most critical factors in determining tree–cattle compatibility. Variability in soil properties, topography, elevation, climatic conditions, logging methods, and cattle management will affect suitability of a site for the integrated use by foresters and ranchers. Well-drained, sandy loam to loam soils with 14–22% of coarse fragments in our study areas limited susceptibility to soil compaction. On the other hand, wetter sites with finer-textured soils under cattle grazing would be at greater risk of significant structural degradation and compaction, and consequently impairment of tree growth.

The findings of this study could help land managers develop plans focused on mortality of lodgepole pine seedlings due to cattle trampling. The successful co-ordination and integration of the timber and range resources will depend on licensees and ranchers working together to predict where problems could arise, and on the development of plans based on sound knowledge.

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