Research Report

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Aspen regeneration, forage production, and soil compaction on harvested and grazed boreal aspen stands

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Abstract

The objective of our study was to determine the effects of timber harvesting and cattle grazing on aspen regeneration, forage production, and soil compaction on aspen cutblocks in the Peace River region of British Columbia. This project was carried out on a long-term study site established 5 km south of Dawson Creek, B.C. Samples were collected and vegetation was assessed during the summer of 2002. Summer and winter harvesting significantly increased aspen stem density relative to unharvested plots, whereas 4 years of cattle grazing had no significant impact on stem density. Inter-tree spacing remained above the postulated minimum of 60–80 cm, indicating that livestock can access the stand. Timber harvesting increased forage production by 69%, while grazing had no effect on forage production. Soil penetration resistance was similar for three harvesting treatments down to a 21 cm depth, while between 21 and 60 cm penetration resistance was consistently the highest on summer-harvested plots, followed by winter-harvested and unharvested plots. Grazing had no impact on soil penetration resistance. The results of this study support the view that cattle grazing and aspen harvesting are complementary land uses for aspen cutblocks on similar sites in the Peace River region; however, proper planning is required to avoid potential cattle distribution problems.

KEYWORDS: *forest grazing, Peace River region, forest soil.*

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Introduction

Cattle grazing of mature trembling aspen (*Populus tremuloides*) stands is a common practice in the Boreal White and Black Spruce (BWBS) biogeoclimatic zone in the Peace River region of British Columbia. Integration of cattle grazing and aspen timber harvesting often leads to conflicts between forest companies and ranchers, especially during stand maturity and the early regeneration phases of the aspen rotation. Forage production tends to increase during the early regeneration phase following aspen clearcutting (Mueggler and Bartos 1977); however, dense stands of root suckers can restrict cattle access to forage and limit the proper distribution of animals (Jones 1974). When no mechanical or chemical thinning is applied to reduce sucker density, reduced access to forage can prevail for 10–15 years, until the stand naturally thins as it matures (Peterson and Peterson 1995).

Forestry-related conflicts regarding cattle grazing on harvested blocks arise because of possible tree damage (through browsing and trampling), decreased plant species diversity, and reduced soil quality (with an emphasis on increased soil compaction). The ranching industry on the other hand is concerned that harvesting reduces the forage value of aspen stands and that cattle access becomes restricted following clearcutting due to the high density of aspen suckers.

To develop sustainable, integrated cattle/silvicultural systems, the forest industry wants to obtain assessments of the long-term effects of cattle grazing on tree growth. These considerations are particularly important in the Interior and Peace River regions of British Columbia where as much as 50% of the range resources in the area occur in aspen communities (Wikeem and Wikeem 1998). A few long-term studies of grazing in aspen cutblocks have been completed in the Peace River region of British Columbia. A study in boreal aspen cutblocks of northeastern British Columbia showed that neither cattle grazing nor timber harvesting had an effect on soil properties (Krzic *et al.* 2003). Effects of cattle grazing on tree growth depend on grazing rate and duration, distribution of cattle over the grazing area, time of year when grazing occurs, and soil properties (e.g., texture, organic matter, and water content). Fitzgerald and Bailey (1984) found that in the aspen parkland of Alberta a single, heavy, late grazing in late August (i.e., approximately coinciding with the expected time of maximum root carbohydrate concentration) nearly eliminated aspen regeneration, whereas early grazing (after emergence of suckers) did not adversely affect aspen suckering.

Effects of cattle grazing on tree growth depend on grazing rate and duration, distribution of cattle over the grazing area, time of year when grazing occurs, and soil properties.

The objective of our study was to determine the effects of harvesting and cattle grazing on aspen regeneration, forage production, and soil compaction in aspen cutblocks of the Peace River region of British Columbia.

Materials and Methods

Site Description

The study was repeated at three sites established from 1989 to 1992 for a long-term study by Hays-Byl (1994). The sites were located within the Bissette Creek drainage (about 5 km south of Dawson Creek) in the BWBS biogeoclimatic zone (55°44'N, 120°11'W) (see Figure 1). Trembling aspen dominates the forest overstorey of the three sites. Soils are generally clay to clay loam Orthic Gray Luvisols developed over morainal deposits. These soils characteristically develop under forest vegetation in sub-humid to humid, mild to cold climates (Soil Classification Working Group 1998). The climate is cool, continental, with cold winters (average temperature for November to February is –11.6°C) and short, relatively warm summers (average temperature for June to

FIGURE 1. Aspen regeneration on a block harvested 12 years ago (foreground) with unharvested aspen in the background, near Dawson Creek, B.C.

TABLE 1. Application dates for timber harvesting and grazing treatments

Treatment	Site 1	Site 2	Site 3
Summer-harvested	1989	1991	1992
Winter-harvested	1989–1990	1991–1992	1992–1993
Grazing	1991–1995	1993–1997	1994–1998

September is 12.9°C). Mean annual precipitation is 487 mm (Environment Canada 1998).

Pure stands of mature aspen were harvested using fellerbunchers, grapple skidders, wood processors, wheel loaders, and crawler tractors. The designated summer-harvested treatment areas were harvested from July to August, while the winter-harvested treatment areas were harvested from November to March (i.e., when soils were frozen).

Following aspen harvesting two grazing treatments (grazed and ungrazed), of approximately 5 ha each, were established at all three study sites. The sites were harvested in different years (Table 1).

Grazing began on June 1 of the year following harvesting and on the same day in each successive year for 4 years at each site. Grazing occurred annually for approximately 2–6 weeks, depending on vegetation growth and animal condition (Hays-Byl 1994). Fourteen heifers and one bull (or 15 heifers and no bulls) were used to achieve 75% use of available forage. The grazing treatments (grazed and ungrazed) were cross-fenced into three timber harvesting treatments (no harvest, summer-harvested, and winter-harvested) (see Figures 2 and 3).

FIGURE 2. Typical understorey on an unharvested aspen area, near Dawson Creek, B.C.

Sampling

Forage Production

Forage production was quantified within two 0.5 m^2 quadrats systematically located along four transects within each treatment unit. Current annual production of all herbaceous species was clipped to ground level in late August 2002 after growth peaked. Current annual growth of shrubs was not clipped. All vegetation samples

FIGURE 3. Typical understorey on a summer-harvested area, near Dawson Creek, B.C.

were stored in paper bags, air-dried, oven-dried at 60°C to constant mass, and weighed.

Stem Density

Stem density of live aspen was determined in two circular subplots along four transects within each treatment unit. All stems considered to be an obstruction to cattle (i.e., stems that had a diameter > 1.5 cm at breast height [DBH]) were counted. Subplot size was altered depending on stem density encountered (25, 50, and 100 m^2).

Soil Compaction

Soil compaction was assessed by measuring soil penetration resistance (Bradford 1986), which was determined to a 60 cm depth at intervals of 3 cm, using a hand-pushed 13 mm diameter cone (30°) penetrometer with data logger (Agridry Rimik PTY Ltd., Toowoomba, QLD, Australia). Soil penetration resistance was measured in October 2002. For each treatment, four transects were established and five profiles were recorded per transect. These transects were established only in the areas without heavy soil disturbance (i.e., landings and skidtrails were not sampled).

Soil water content was determined gravimetrically (Gardner 1965) on samples taken in October 2002 from depths of 0–7.5, 7.5–15, and 15–30 cm. Since the soil water content at the time of measurement strongly affects soil penetration resistance, correction to a reference soil water content was done using the method proposed by Busscher and Sojka (1987). This method applies a logarithmic empirical relationship among bulk density, gravimetric water content, and penetration resistance, which allows comparisons of absolute penetration resistance measurements independent of the original soil water content. Corrections were adjusted to a reference water content of 0.25 kg/kg, an average value for the three study sites at the time of penetration resistance measurements.

Statistical Analyses

Forage production, aspen stem density, and soil penetration resistance data were analyzed as a split-plot randomized complete block design, with three replications and four sampling units (transects) per plot. Timber harvesting was considered the main plot treatment, grazing was the subplot treatment, and the three sites were considered replicates. Analysis of variance (SAS Institute 1990) was used to test for significant differences in forage production, aspen stem density, and soil penetration resistance. Orthogonal contrasts were used to test for differences among means or groups of means. Differences were considered significant ($p < 0.1$), unless stated otherwise.

Results and Discussion

Forage Production

Clearcut aspen harvesting increased herbaceous forage production by 69% compared with unharvested stands. Harvested stands produced an average of 847 kg/ha of forage, whereas unharvested stands produced 499 kg/ha (Figure 4). Most of the forage in the understorey of both clearcuts and mature stands consisted of bluejoint reedgrass (*Calamagrostis canadensis*), a relatively palatable species (Krzic *et al*. 2003). A mix of forbs of low abundance accounted for the majority of other available forage (Table 2).

The increased forage production ($p < 0.05$) following harvesting is consistent with most other studies. Bartos and Mueggler (1982) studied changes in aspen reproduction, and understorey production and composition, for 3 years following clearcutting in Utah. Understorey production on the cut units increased from 1013 kg/ha before cutting to 3000 kg/ha after three growing seasons. Production on the uncut control areas increased from 1199 to 1539 kg/ha during the same period. The authors attributed the significant increase in understorey production to the reduction in competition from the removal of the aspen overstorey. Bailey (1991) inspected cutblocks and adjacent mature

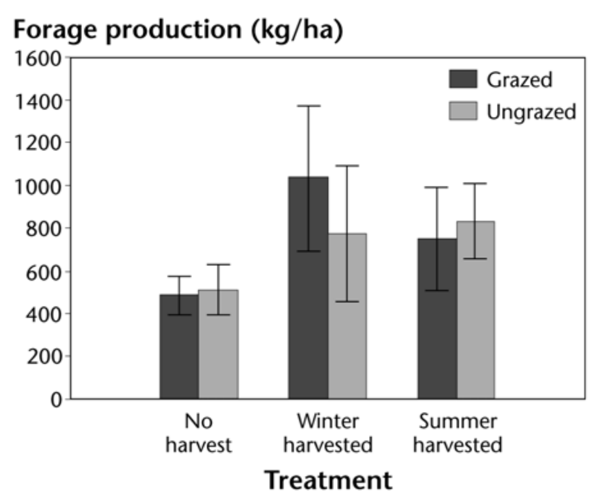

FIGURE 4. Effect of harvesting and grazing on forage production (kg/ha). Error bars represent standard error of the mean.

TABLE 2. Description of the plant community (data from Krzic *et al.* 2003)

	Canopy cover (%)	
Plant species	**Harvested**	**Unharvested**
GRASSES		
Calamagrostis canadensis	22.4	17.9
Elymus glaucus	1.4	2.2
FORBS		
Aralia nudicaulis	1.7	2.0
Arnica cordifolia	0.9	4.4
Aster ciliolatus	2.7	1.9
Cornus canadensis	3.3	6.0
Epilobium angustifolium	4.4	3.4
Fragaria virginiana	3.1	1.3
Galium boreale	1.4	0.9
Maianthemum canadense	1.5	0.8
Mertensia paniculata	3.8	3.7
Petasites frigidus	2.2	0.8
TREES AND SHRUBS		
Alnus incana	5.2	20.1
Amelanchier alnifolia	2.0	1.1
Cornus stolonifera	2.1	1.1
Larix occidentalis regeneration (< 5 m)	1.8	2.3
Linnaea borealis	1.2	2.9
Lonicera involucrata	1.5	1.1
Populus balsamifera regeneration (< 5 m)	8.6	2.8
Populus tremuloides regeneration (< 5 m)	44.9	0.0
Rosa acicularis	14.8	12.1
Rubus idaeus	3.7	1.4
Rubus pubescens	3.2	3.3
Shepherdia canadensis	1.5	1.2
Spiraea betulifolia	2.4	0.0
Viburnum edule	4.9	5.4

aspen forest near Dawson Creek, B.C. He reported that forage production was lower in the first growing season in clearcuts, but was greater in the second and third years by two and three times that of the aspen forest.

Stands harvested in the winter produced more ($p = 0.02$; Table 3) forage than stands harvested in the summer. Average forage production on winter-harvested stands was 903 kg/ha, while summer-harvested stands produced an average of 791 kg/ha. Winter harvesting generally results in lower soil disturbance and losses of nutrients relative to harvesting performed in summer (McLeod 1988; Maynard and MacIsaac 1998). On these sites, winter harvesting may have led to greater forage production than summer harvesting because of less physical disturbance to the herbaceous layer.

Soil Compaction

Soil compaction is a process of densification in which soil strength is increased, and porosity and permeability are reduced, as a result of the application of external stresses. Commonly, soil compaction is measured by either bulk density or soil penetration resistance. The latter is considered to approximate the resistance encountered by plant roots growing in the soil.

In our study, soil penetration resistance was similar on unharvested, winter-, and summer-harvested treatments to a depth of 21 cm (Figure 5). Below 21 cm, penetration resistance was consistently the highest on the summer-harvested treatment, followed by the winter-harvested and unharvested treatments. Soil water content

TABLE 3. Contrast tests for forage production means

Contrast test	*F*-values	*ndf*[a]	*ddf*[b]	*P* > *F*
Unharvested vs. harvested	125.57	1	6	0.00003
Summer-harvested vs. winter-harvested	9.74	1	6	0.021

[a] Numerator degrees of freedom.
[b] Denominator degrees of freedom.

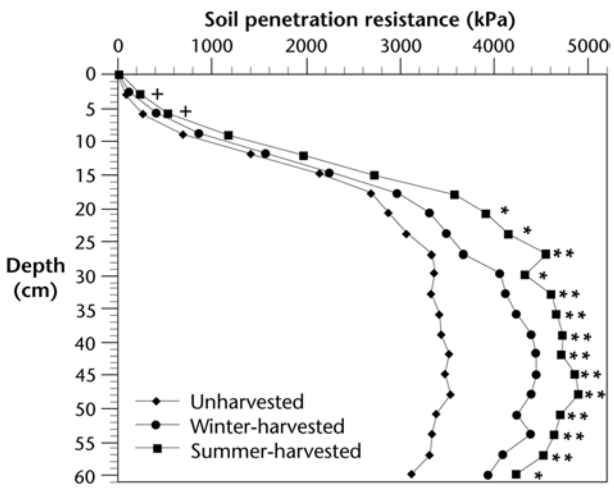

FIGURE 5. Soil penetration resistance data obtained in October 2002 on unharvested, winter-harvested, and summer-harvested treatments near Dawson Creek, B.C. Means followed by +, *, and ** are significantly different at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

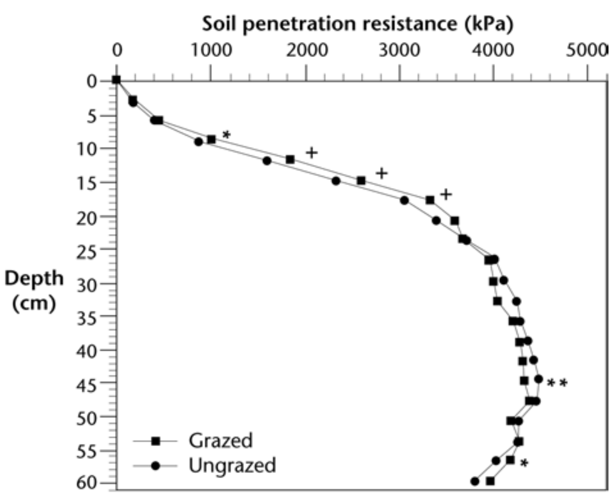

FIGURE 6. Soil penetration resistance data obtained in October 2002 on ungrazed and grazed treatments near Dawson Creek, B.C. Means followed by +, *, and ** are significantly different at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

has a profound effect on trafficability and resistance to compaction (Greacen and Sands 1980). Restricting the use of heavy logging machinery to when soil water content is low greatly reduces compaction. Operating on frozen ground or when soils are covered with snow also reduces compaction (Smith and Wass 1976; McLeod 1988). Our data show that even 11 years after harvesting, soil compaction was still significantly lower on winter-harvested treatments (done when soils were frozen and [or] covered with snow, and when soil water content was low) than on summer-harvested treatments.

Soils high in clay particles, such as clay to clay loam Luvisols of the Peace River region, are very highly susceptible to soil compaction from the use of heavy logging equipment (Cromack *et al.* 1978; B.C. Ministry of Forests 1999). Hence, summer skidder/crawler tractor logging operations should be avoided on these sites.

Cattle grazing had no effects on soil penetration resistance (Figure 6), except at depths of 9 and 57 cm, where soil penetration resistance was greater on grazed than on ungrazed treatments ($p < 0.05$).

Below the depth of 15 cm soil penetration resistance on all treatments was consistently greater than 2500 kPa, a commonly cited critical value for root penetration and growth (Greacen *et al.* 1969; Greacen and Sands 1980; Busscher *et al.* 1986). This is an indication that soil strength likely was limiting to root growth at depths below 15 cm. Similarly, a study by Bulmer and Krzic (2003), also carried out on clay loam Luvisols in the Peace River region of British Columbia, showed that tree

Restricting the use of heavy logging machinery to when soil water content is low, or operating on frozen ground or when soils are covered with snow reduces compaction.

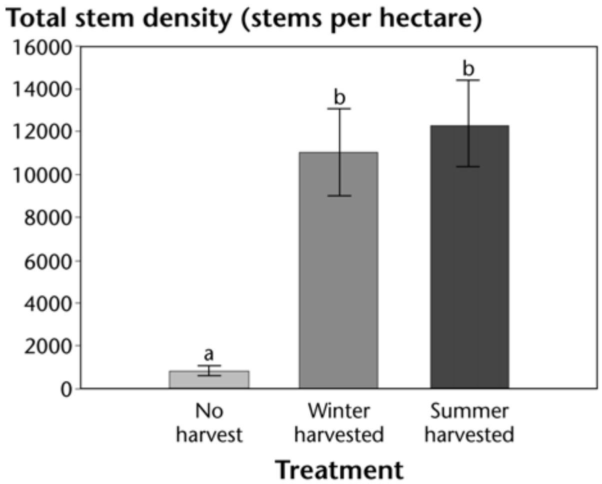

FIGURE 7. Total stem densities for unharvested, winter-harvested, and summer-harvested sites. Among treatments, means with different letters differ significantly at $p < 0.05$. Error bars represent standard error of the mean.

roots had access to about 10 cm of soil where penetration resistance was lower than 2500 kPa. However, similar aspen stem densities on summer- and winter-harvested treatments (Figure 7) indicate that relatively high soil penetration resistance was not limiting for aspen regeneration on these sites. It is possible that roots were able to explore various cracks commonly present in the deeper parts of soil profile on the fine-textured soils such as these.

Stem Density

Harvesting increased the stem density of pole-sized live aspen by 17 times (i.e., from 702 to 11 626 stems per hectare), but season of harvesting had no effect on stem density (Table 4). Livestock access may be constrained by dense aspen regeneration when aspen reaches a size where it presents a physical barrier (> 1.5 cm DBH in this study). The degree of access constraint is likely related to inter-tree spacing at this growth stage. An inter-tree spacing of 60–80 cm or less (28 000–16 000 stems per hectare) represents an impenetrable barrier for mature cows (American Society of Agricultural Engineers 1996). Other factors may also cause cattle to avoid areas of dense regeneration. For example, innate preferences for certain habitat characteristics may cause cattle to select areas with certain levels of openness.

In this study, the average stem density of harvested stands is equivalent to an inter-tree spacing of 93 cm and should not be physically limiting to cattle access. Although it is physically possible for cattle to use areas of dense aspen regeneration, observation suggests that these areas are generally avoided in favour of roadsides, landings, and other openings (P. Grilz, B.C. Ministry of Forests, Prince George, B.C., pers. comm., 2003). Potential cattle distribution problems can be minimized if cattle access is considered at the planning stage.

Studies by Maine and Horton (1966) and Hungerford (1998), also carried out in northern climates, reported lower suckering densities after harvesting as a result of cooler soil temperatures. It is possible that both winter- and summer-harvesting treatments led to a reduction of soil temperature relative to the unharvested treatment. Creation of less than optimal environmental conditions for aspen suckering on both harvesting treatments resulted in the lack of difference in stem density between winter- and summer-harvesting treatments. Low suckering densities were also reported on sites that have been quickly invaded by grass following the timber harvest (Landhausser and Lieffers 1998). Krzic *et al.* (2003) showed significant increases in bluejoint reedgrass on the winter-harvested treatments, but grass competition did not seem to affect suckering densities in our study.

TABLE 4. Mean aspen stem density (stems per hectare) obtained on October 2002 for all treatment combinations

Timber harvesting treatment	Grazing treatment	Live aspen stems (stems per hectare)	Standard error
Unharvested	Ungrazed	611	191
	Grazed	792	29
Summer-harvested	Ungrazed	14 717	3548
	Grazed	9 863	2450
Winter-harvested	Ungrazed	11 150	4196
	Grazed	10 775	1913

There was no grazing effect on aspen stem density within the winter- and summer-harvested treatments (Table 4), which is in agreement with the lack of a grazing effect on soil compaction (Figure 6). Fitzgerald and Bailey (1984) and Bailey *et al.* (1990) have found that only late-season, short-duration, high-intensity grazing has a significant effect on the density of aspen suckers within clearcuts. Grazing treatments in the present study are not considered late-season, short duration, or high intensity.

Eleven years after timber harvesting, soil compaction was significantly lower on winter- than summer-harvested areas, indicating the importance of restricting the use of heavy logging machinery to times when soil water content is low.

Conclusions

Eleven years after timber harvesting, soil compaction was significantly lower on winter- than summer-harvested areas, indicating the importance of restricting the use of heavy logging machinery to times when soil water content is low (e.g., during winter when soil is frozen or covered with snow).

Forage production increased by 69% following harvesting. This increase in forage (mostly bluejoint reedgrass) represents a significant resource benefit to the ranching industry. Aspen stem density was 17 times greater on harvested than unharvested treatments, due to suckering promoted by harvesting disturbance. Inter-tree spacing remained above the level at which cattle cannot physically access the stand. Nonetheless, observation of comparable operational situations suggests that cattle tend to avoid areas of dense aspen regeneration in favour of roadsides, landings, and other openings.

The results of the present study support the view that cattle grazing and aspen harvesting are complementary land uses for aspen cutblocks in the Peace River region; however, proper planning is required to avoid potential cattle distribution problems.

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