Boreal Science

Testing Sheep Grazing as a Vegetation Management Tool in Northeastern Ontario

NEST Technical Report TR-041
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Abstract

We investigated sheep grazing as an alternative method of controlling competing vegetation in conifer plantations in northeastern Ontario. Our objectives were to determine grazing effects on the establishment of tree seedlings and on non-crop vegetation dynamics. The three crop tree species studied were jack pine (*Pinus banksiana*) on two sites, one in Chappise Township, established in 1991, and one in Silk Township established in 1992; black spruce (*Picea mariana*) on one site in Mortimer Township established in 1992; and white spruce (*Picea glauca*) in Macklem Township (Gibson Lake Road) established in 1993. Grazing was done for one season at each site. We recorded seedling height and stem diameter at 10 cm above the root collar and competing vegetation height and percent cover by species. The seedlings were measured annually at the Chappise and Silk sites for two years post-grazing and the Mortimer and Gibson Lake Road sites for three years. We measured competing vegetation before grazing started, shortly after grazing finished, and for most trials, during the second growing season after grazing. Final measurements were at the end of the first post-grazing growing season for the Chappise site and at the end of the third growing season for the Gibson Lake Road site. We combined percent cover data into seven classes (trees, shrubs, broadleaf herbaceous, graminoids, woody, herbaceous, and total cover). Crop tree seedlings generally did not show a response to grazing. Percent cover of competing vegetation was greatly reduced after treatment, but recovered rapidly and did not differ from control plots by the final measurement. Sheep grazing appears to be an unsuitable alternative for controlling competing vegetation on reforested sites in northeastern Ontario.

Background

Vegetation control on reforested lands is usually necessary to ensure the survival of planted stock and the rapid renewal of conifer cover. Failure to control competing vegetation can delay renewal of conifer cover and lead to site conversion to hardwood dominated stands. On highly competitive sites, herbaceous species such as Canada bluejoint grass (*Calamagrostis canadensis*), or shrubs such as speckled alder (*Alnus incana*), wild red raspberry (*Rubus idaeus* spp. *melanolasius*) and willows (*Salix* spp.) can also take over and limit conifer seedling establishment.

Aerial spraying of herbicides has long been the tool of choice for controlling competitive vegetation in Ontario. In 1991, about 94 percent of the 95,700 ha tended in the province were treated with herbicides (Environics Research Group 1992). Manual or mechanical methods (e.g. brushsawing) account for the rest of the tended area. This is happening at a time when most people in Ontario (81 percent) are opposed to the use of chemicals in the forest (Environics Research Group 1992).

Because of public concern about herbicide use for vegetation control in forests, the province of Ontario initiated an investigation into alternatives to aerial spraying of herbicides to control forest vegetation (OMOEE 1994) through the Vegetation Management Alternatives Program (VMAP). In 1991 as part of the VMAP initiative, Northeast Science and Technology (NEST) in Timmins began to investigate the use of sheep grazing to control vegetation in reforested areas. Five sheep grazing trials were established in northeastern Ontario between 1991 and 1995 (Figure 1, Table 1) including the Chappise trial established in 1991, the Mortimer & Silk trials established in 1992, the Edwards trial established in 1994 and the Gibson Lake Road trial established in 1995. These trials examined the impact of one season of sheep grazing on crop trees and competing vegetation. This report discusses results and recommendations for future study.

Table 1. Site and design features for five sheep grazing trials conducted between 1991 and 1995 in northeastern Ontario.

Site Name	Chappise	Mortimer	Silk	Edwards	Gibson L. Road
MNR District	Chapleau	Cochrane	Chapleau	Cochrane	Timmins
Crop species	jack pine	black spruce	jack pine	black spruce	white spruce
Sampled trees	120	250	250	-	1450
Trial area (ha)	3.5	10	10	50	27.5
Year grazed	1991	1992	1992	1993	1995
Grazing period	21 days, August	June 29 July 15 August 2 - 18	July 16 - August 1 August 19 - September 5	Late June - Late August	June 18 - August 15
Number of sheep	53	120 ewes, 70 lambs	120 ewes, 70 lambs	600	450
Number of blocks	6	5	5	N/A	15

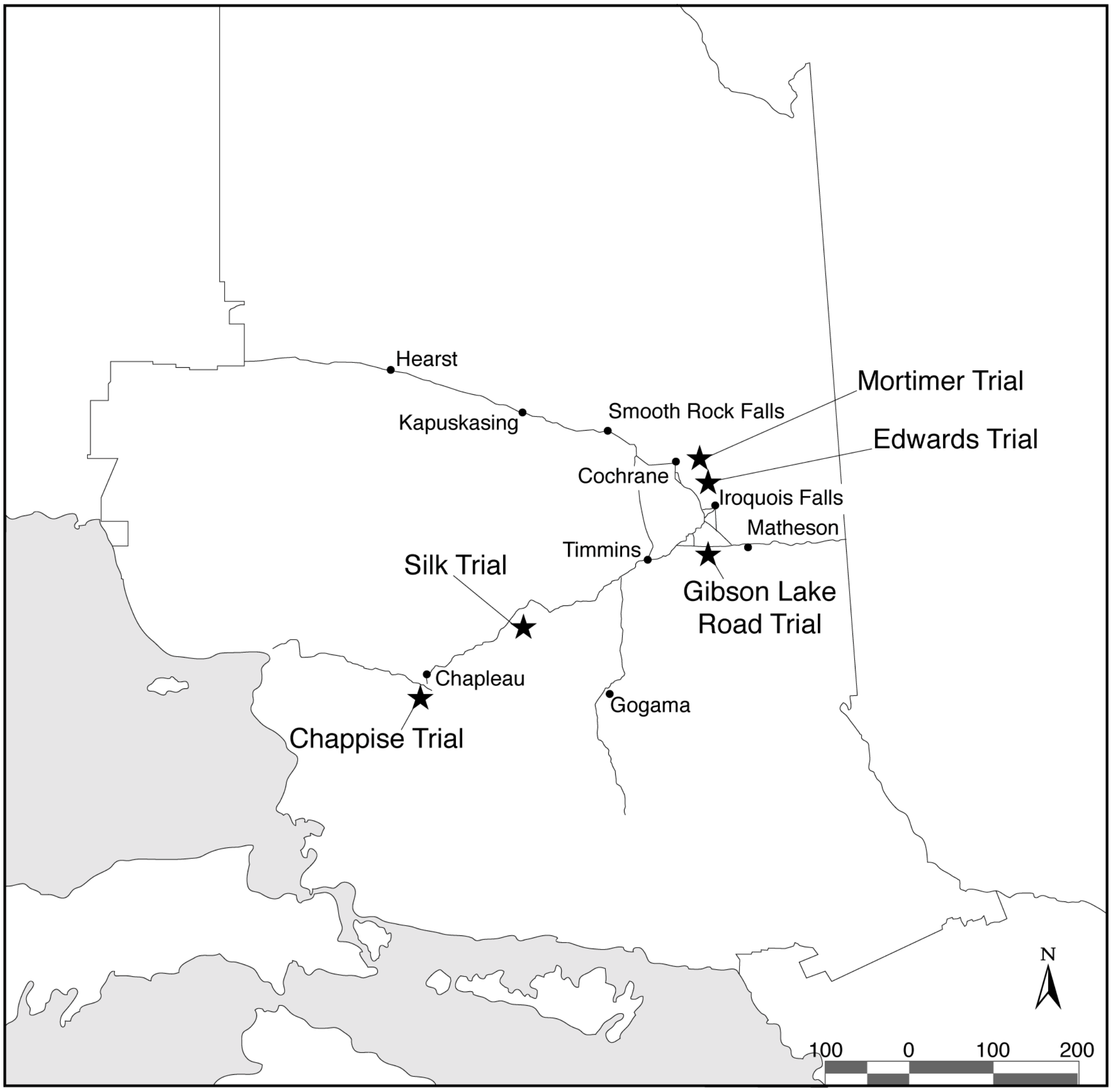


Figure 1. Sheep trial locations in northeastern Ontario

Use of sheep grazing in other jurisdictions

Sheep have been used in agroforestry applications in several locations around the world. In Greece, sheep are used to graze reforested areas to reduce grass cover and decrease the fire hazard in plantations (Papanastasis *et al*. 1995). Sheep and other livestock have been used in reforested areas in the western United States since the 1960s, especially in Oregon and California (Hendrick and Keniston 1966). Sheep and radiata pine (*Pinus radiata*) are combined in agropastoral systems in New Zealand and Australia (Anderson *et al.* 1988), where the pine is intensively managed for sawlogs and sheep grazing is allowed on the same land to provide additional financial returns for the landowner.

British Columbia has been actively using sheep as a vegetation management tool since the mid-1980s, mainly in response to pressures from the agricultural community for more grazing lands (Sutherland *et al.* 1991). In 1992, over 26,000 sheep grazed on B.C. cutovers for controlling fireweed (*Epilobium angustifolium*) and other species.

Previous research trials

The first research trial for investigating sheep grazing and conifer plantations started in 1952 in Oregon (Hendrick and Keniston 1966). Since this first trial, other western states have investigated the use of livestock for vegetation control in plantations. Oregon has examined the use of cattle (Doescher *et al.* 1989, Karl and Doescher 1993) and sheep (Jaindl and Sharrow 1988, Leininger *et al*. 1989, Leininger and Sharrow 1989) in plantation areas. British Columbia has had over 50 trials (e.g. Tweedhope 1985, Sutherland 1986, Lousier 1990, Lousier and Lousier 1991, Negrave 1993, Hays 1994). O'Brien and Bailey (1987) have examined sheep grazing for vegetation control in Alberta.

Vegetation responses to grazing have varied. In almost all studies sheep effectively controlled competing vegetation and significantly reduced their coverage. Fireweed and blue-joint grass coverage was effectively reduced by sheep in B.C. trials (Sutherland 1986, Bancroft 1992a, 1992b, Negrave 1993). Other palatable species, especially legumes, grasses and willows, are sought out by sheep and effectively reduced (Newsome 1993, Hays 1994). The downside however, is that species that are unpalatable to sheep can increase their coverage and become competitors. When grazing is stopped, vegetative cover usually returns quickly to pregrazing levels, sometimes by the following season (Bancroft 1991, 1992b).

Crop tree response to grazing varies. Studies have found no effect on height or diameter growth of Douglas-fir seedlings (*Pseudotsuga menziesii*) after nine years of grazing (Allen and Bartolome 1989) and ponderosa pine (*Pinus ponderosa*) after five years of grazing (McDonald and Fiddler 1987). One season of grazing did not influence western red cedar (*Thuja plicata*) growth in a mixed Douglas-fir, western red cedar and grand fir (*Abies grandis*) plantation on Vancouver Island (Lousier 1990) or white spruce (*Picea glauca*) growth in a northern British Columbia plantation (Negrave 1993). Douglas-fir reacted negatively to grazing in the same plantation on Vancouver Island (Lousier 1990) with better height growth in control plots compared to grazed plots.

Other studies have found a positive growth response. Seedling volume increased significantly after three years of cattle grazing in a Douglas-fir / ponderosa pine plantation. This was attributed to moisture competition, as the study area in southwest Oregon has periodic summer droughts (Doescher *et al*. 1989). Grand fir responded to grazing with improved height growth in a mixed plantation on Vancouver Island (Lousier 1990). Six years of spring grazing in a Douglas-fir plantation resulted in significantly larger trees in the grazed sites compared to the control sites but there were no differences after 20 years (Jaindl and Sharrow 1988). Hays (1994) found that at least two years are required after the initial grazing before crop trees show positive growth responses.

Trial Objectives

There were several objectives to these trials, including:

- comparing growth and survival of tree seedlings between grazed and control blocks
- determining whether sheep will selectively eat competing vegetation without unacceptable environmental risk or damage to conifer seedlings
- determining whether sheep can gain adequate weight on plantations
- comparing growth of competing vegetation between grazed and control blocks over time.

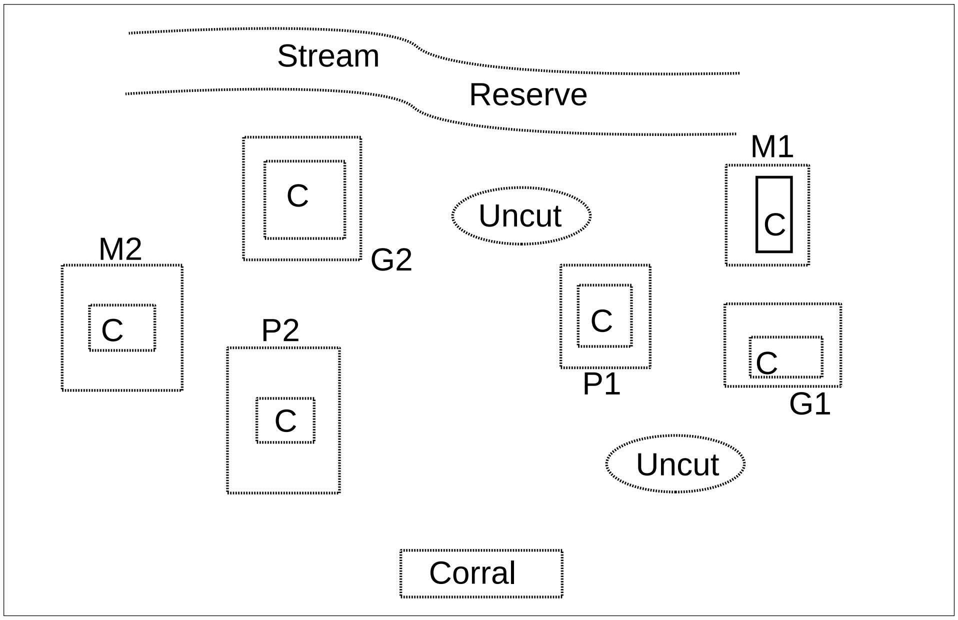


Figure 2: Block Layout for Chappise Township trial. C indicates control subplots. M indicates mixed vegetation; P designates poplar dominated vegetation; G represents grasses as dominant. Not to scale.

Site Descriptions

Chappise Township: This site is located southwest of Chapleau (Figure 1). The original stand was a conifer mixedwood stand that was clearcut and replanted to jack pine (*Pinus banksiana*) in 1989. Six plots were randomly located on the site and designated as poplar 1 (P1), poplar 2 (P2), grass 1 (G1), grass 2 (G2), mixed 1 (M1) and mixed 2 (M2), depending on the dominant vegetation type (Figure 2, Table 1). The centre of each plot was fenced to exclude the sheep and act as a control. This trial and the following two trials were set up as a split block design. All crop trees on all trials were identified with aluminium tags attached to steel pins.

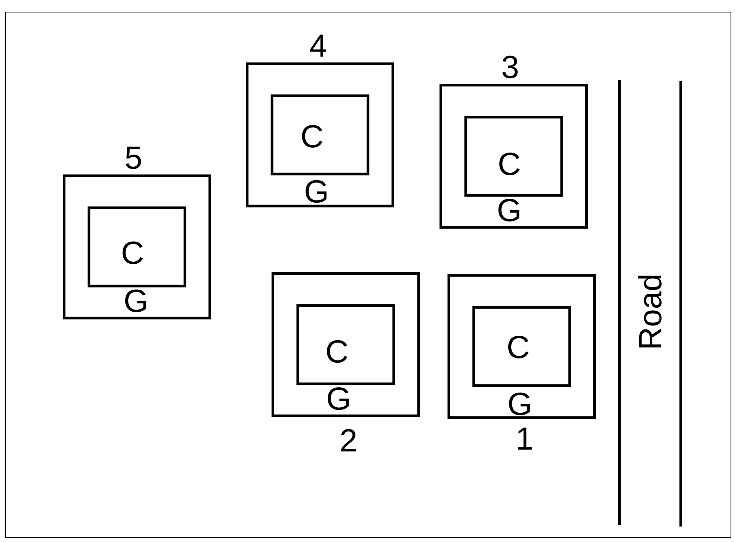


Figure 3: Block layout for Mortimer Township trial. C indicates control subplots and G indicates grazed subplots. Not to scale.

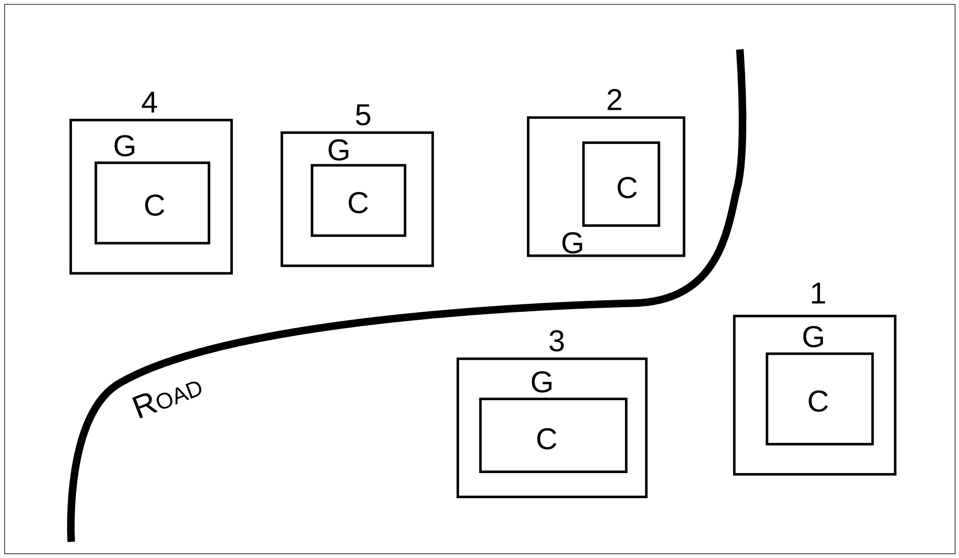


Figure 4: Block layout for Silk Township trial. G indicates grazed and C indicates control portions of blocks. Not to scale.

Mortimer and Silk Townships: The Mortimer site is located north of Iroquois Falls (Figure 1). The original stand was clearcut in 1987, shearbladed in the winter of 1988-89, and planted with black spruce (*Picea mariana*) paperpot stock in 1989.

The Silk site is located south of Foleyet (Figure 1). It was clearcut in 1988, windrowed in 1989 and planted with jack pine stock in 1990.

The trials covered 10 ha at each site. Each trial had five 0.04 ha fenced exclosures with 25 tagged trees per plot (Figures 3, 4, Table 1). Each trial was grazed twice.

Edwards Township: This site is located just south of the Mortimer trial (Figure 1) and was used as an operational trial in 1993 for testing the logistics and maintenance of a full-scale operational sheep graze (Table 1). Overwintered black spruce container stock were planted in May 1992. Stocking was low in 1993 and the surviving trees showed signs of competition stress. Competition on the site was mainly from Canada blue-joint grass and wild red raspberry.

Gibson Lake Road (German Township): This site is located about 28 km east of Porcupine and near the junction of Highway 101 and Gibson Lake Road. This location made it the most visible to the public. The original stand was a jack pine-aspen-birch mixedwood that was cut in 1993. Bareroot white spruce seedlings were planted in 1994. The trial was set up as a randomised complete block design with five treatments and three replicates (15 blocks in all) (Table 1, Figure 5). Within each block ten 25 m^2 circular plots were randomly located and all white spruce within the plot were pinned and numbered. The five treatments were:

- graze for maximum removal in June,
- graze for maximum removal in July,
- graze for maximum removal in June and in July,
- backpack spray with glyphosate, and
- control.

The ecosites in the trial area are a jack pine on deep, fresh, sandy to coarse loamy soils (2a) and a coniferous mixedwood on fresh to moderately moist, sandy to coarse loamy soils (3b) (McCarthy *et al.* 1994).

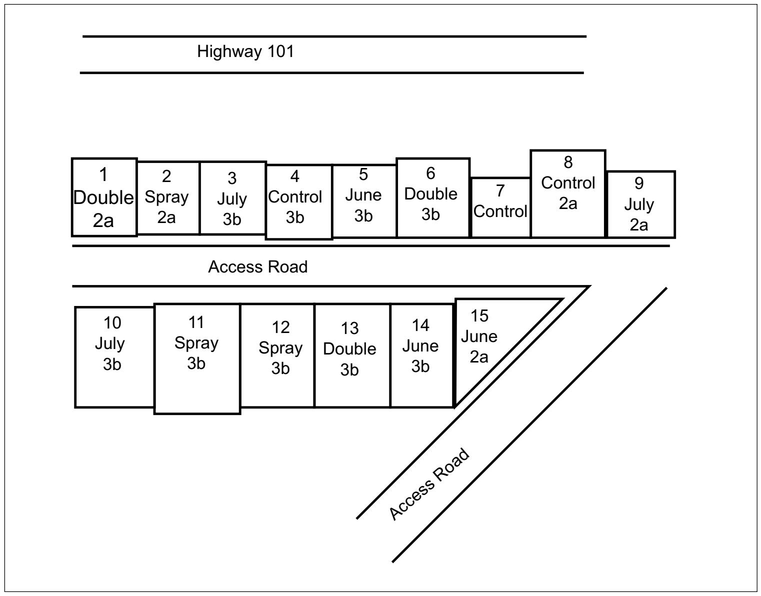


Figure 5: Block layout for Gibson Lake Road trial. Block number, treatment and ecosite are given for each block. Not to scale.

This trial had two objectives in addition to the overall objectives. They include:

- determine the most effective timing and duration of grazing sheep on spruce plantations
- compare crop tree response to herbicides and sheep grazing.

Data collection

Crop tree heights were measured to the nearest 0.1 cm. Diameter measurements were made to the nearest 0.1mm at 10 cm above ground. Pre-treatment measurements were made before the start of the growing season, and post-treatment measurements were made at the end of the growing season. Seedling volumes were calculated using the formula for a cone, $V=0.33\pi r^2 h$, where V=volume in cm^3, r=seedling radius in cm, and h=seedling height in cm.

Crop tree measurements were conducted for three growing seasons at the Chappise, Silk and Mortimer trials (treatment year and two years post-treatment). In the treatment year, two measurements were made, one before and one after treatment. A third post-treatment measurement was done at the Mortimer and Gibson sites. Vegetation data was collected for pre-and immediate post-treatment cover during the treatment year at Chappise, Mortimer and Silk. At Chappise the third vegetation survey was conducted one year after treatment, and at Silk and Mortimer two years later. At the Gibson Lake Road site, the post treatment survey was conducted a year after treatment, rather than in the same year, and the final survey three years after treatment.

Competition data was collected on all vegetation within 1.13 m (area=4 m^2) of the crop tree. We identified each species, measured the mean height to the nearest cm, and visually estimated the percent cover. In the Gibson Lake trial, we separated herbaceous vegetation into two height classes; greater than 20 cm and less than or equal to 20 cm. Surveys were done before grazing started, shortly after grazing finished, and for most trials, during the second growing season after grazing.

Data analyses

All analyses were performed with Statgraphics Version 7 (Manugistics Inc. 1993). Data were log or square root transformed where necessary. Nonparametric tests were used when transformation did not allow for homogeneous variances.

Crop tree growth - Analysis of variance was used to determine whether grazing influenced conifer seedling growth. Means used in the analyses were based on means per treatment block.

Competing vegetation analyses - Percent cover by species was pooled into several classes for determining percent changes in vegetation cover over time and between treatments. These classes are:

- trees
- shrubs
- broadleaf herbs
- graminoids
- woody (trees and shrubs)
- herbaceous (broadleaf herbs + graminoids)
- total cover

Total vegetative cover can exceed 100 percent as the original data was pooled into the different classes (and this was not done in the field). Different species will naturally overlap each other. We used analysis of variance to determine if the following differences between percent cover existed between control and treated sites at the following times:

- pregrazing
- immediate postgrazing (fall of treatment year)
- final survey
- pregrazing and final survey.

Woody competition heights - Analysis of variance was used to determine if heights of the most common trees and shrubs for each trial were affected by grazing. Block means were used for each species in the analysis.

Results

The Chappise Trial

Sheep Responses

The trial did demonstrate that sheep will eat competing vegetation. Some jack pine had the tips nipped off by sheep, but damage was considered insignificant and was not recorded. Veterinary inspections found that sheep maintained their weight and health during the course of the trial. It is not known whether this is comparable to the weight gain for sheep on normal pasture. Some of the sheep had come off of a feedlot, and were already in excellent condition, so being on the poorer range may not have had much of an effect.

Seedling responses

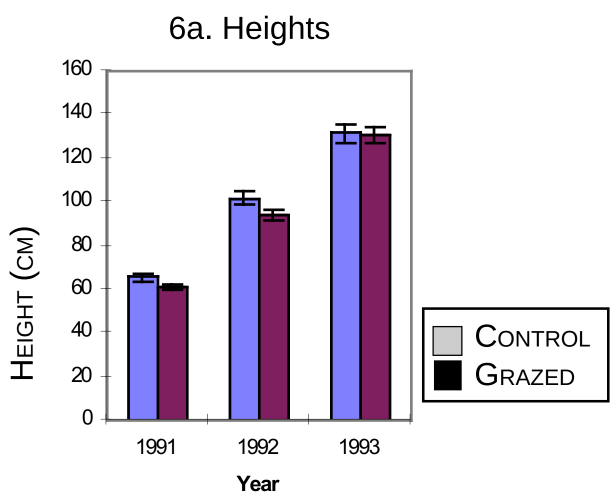
Seedlings did not differ in heights between control and treatment blocks before grazing (Figure 6a, ANOVA, d.f.=11, F-ratio=1.69, p=0.25). Grazing had little influence on jack pine seedling growth. It did not promote seedling height growth (Figure 6a, ANOVA, d.f.=11, F-ratio=1.49, p=0.3; 1993, ANOVA, d.f.=11, F-ratio=0.08, p=0.8) or seedling diameter growth (Figure 6b, 1992, ANOVA, d.f.=11, F-ratio=0.2, p=0.7; 1993, ANOVA, d.f.=11, F-ratio=0.6, p=0.5) within the three-year survey period. Grazing did not influence seedling volume at any time (Figure 6c). Seedling survival was high (91 percent after three years) and did not differ between treatments (T-test, p=0.7).

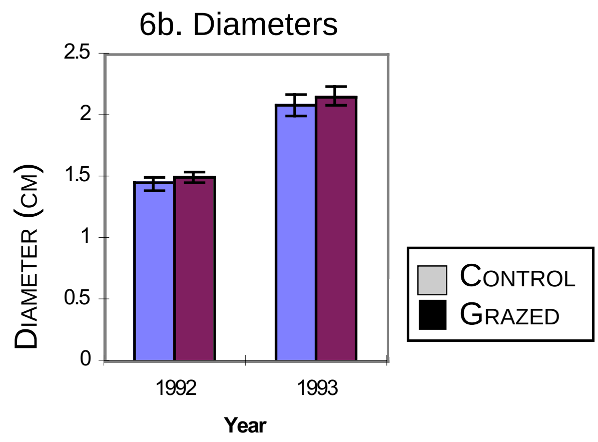
Vegetation responses

Woody species analysed for height responses to sheep grazing include white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), jack pine, blueberry (*Vaccinium* spp.), bush honeysuckle (*Diervilla lonicera*), Labrador-tea (*Ledum groenlandicum*), pin cherry (*Prunus pensylvanica*), mountain-ash (*Sorbus* spp.), wild red raspberry, skunk currant (*Ribes glandulosum*) and willow. Initial heights for all species were similar between control and grazed plots (Table 2, ANOVA, p>0.05). Aspen showed a positive, significant response (ANOVA, F-ratio=17.1, p=0.014) to grazing with greater mean heights in the treated plots (mean height=146 cm) compared to the control plots (mean height =104 cm). By the following year, heights were similar between control and grazed plots for all species tested (Table 2, p>0.05).

Grazed plots had significantly more percent cover of all vegetation classes before grazing (ANOVA, p<0.04), except for graminoids (Table 3, ANOVA, p=0.5). Grazing reduced the percent cover of each vegetation class so that it was similar to the percent cover in the control plots immediately after grazing (ANOVA, F-ratio<5.0, p>0.05). Shrub and woody cover in the control plots was significantly greater in the grazed plots the following season (Table 3, shrubs, ANOVA, F-ratio=10.9, p=0.02; woody, ANOVA, F-ratio=8.8, p=0.03).

Most of the vegetation had not recovered from grazing by 1992. Percent cover for all classes except trees and graminoids were significantly reduced in 1992 compared to the initial coverage (t-test, T-statistic $\geq$ 4.12, p $\leq$ 0.001). Control plots did not have any change in percent cover for any vegetation class between initial and final surveys.





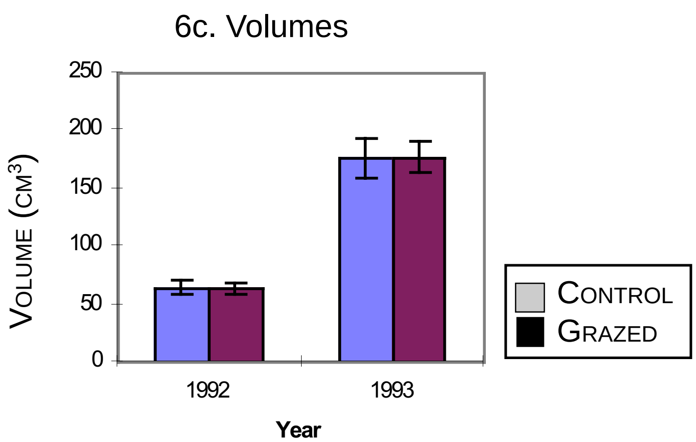


Figure 6. Chappise trial crop tree responses by year; (a) heights, (b) diameters, (c) volumes. Diameters were not recorded in 1991.

Table 2. Mean heights (± S.E.) (cm) of competing woody species at the Chappise trial site.

Species and treatment	Initial June 1991			Postgraze September 1991			Final August 1992		
	n	Mean	S.E.	n	Mean	S.E.	n	Mean	S.E.
Blueberry									
Control	5	20.4	2.2	5	24.5	2.5	6	21.8	1.5
Grazed	6	22.9	2.3	6	26.9	0.9	6	23.2	2.2
Bush honeysuckle									
Control	4	33.7	4.8	4	42.7	6.2	4	34.2	5.4
Grazed	3	44.3	3	4	30.8	5.4	6	30.5	1.5
Jack pine									
Control	4	36.4	12.1	4	35	13.3	3	77.9	21.1
Grazed	6	42	8.1	6	44	9.1	6	61.9	11.7
Labrador-tea									
Control	4	32	1.5	4	34.7	1.8	3	31.7	1.7
Grazed	5	31	4.8	5	33.5	3	5	37	5.4
Mountain-ash									
Control	3	81	19.5	3	84.8	2.9	4	87.2	33.8
Grazed	5	87.6	12.9	5	74.8	19	5	64.4	19.1
Pin cherry									
Control	5	90.1	12.3	5	85.9	11.6	5	100.1	16.1
Grazed	6	84	5.7	6	85.2	7.1	6	79.5	18.7
Raspberry									
Control	5	32.8	2.1	5	28.7	3.8	6	26.4	3.7
Grazed	6	34.8	3.4	6	33.9	4	6	24.4	4.7
Skunk currant									
Control	4	25.5	2.3	4	23.9	1.2	5	24.9	1.6
Grazed	6	20.5	2.3	6	23.4	3.9	6	22.7	3.1
Trembling aspen									
Control	4	119.4	11	5	107.3	11.4	6	134.1	14.1
Grazed	6	134.3	11.3	6	146	4.9	6	146	7.7
White birch									
Control	3	43.5	7.5	3	47	4.6	5	34.8	9.7
Grazed	4	45.7	8.3	5	47.5	10.9	5	41.5	14.3
Willow									
Control	5	77.8	10.1	5	73	11.3	6	74.2	13.3
Grazed	6	75.1	13.6	6	75.6	12.9	6	82.4	16.6

Table 3. Mean percent cover (± S.E.) by treatment and survey period for seven vegetation classes at the Chappise trial site.

Vegetation class	Initial June 1991				Postgraze September 1991				Final August 1992			
	control	S.E	grazed	S.E.	control	S.E.	grazed	S.E.	control	S.E.	grazed	S.E.
Trees	6.5	2.4	9	2.3	8.9	2.3	6.1	1.6	10.2	3.8	8.2	2.9
Shrubs	26.9	3.1	40.9	4.4	31.6	3.2	27.6	3.8	29.4	4.8	19.7	2.4
Broadleaf herbs	9.8	3.5	19.9	5.2	14.5	4	11.8	1.3	8.6	2.9	9.7	3.1
Graminoids	13.5	5.2	15.7	3.5	15.1	4.4	14.4	3.3	6.9	1.7	10.1	3.2
Woody	33.4	2.8	49.8	5.1	40.6	2.6	33.8	3.1	39.6	6	27.9	3.1
Herbaceous	23.3	4.5	35.6	4.9	29.6	3.8	26.2	3.5	15.5	2.1	19.7	3.3
Total cover	56.7	3.2	85.4	6.6	70.2	4.6	59.8	4.4	55.1	6.2	49.3	6.4

The Mortimer Trial

Sheep responses

Sheep gained an average of 0.077 kg/day during the length of the grazing period (66 days) on this trial and the Silk trial. This was only half of the weight gain rate (0.156 kg/day) when the same sheep were put on pasture for 34 days after the trial. There was some supplemental feeding with hay at the start of the trial before the sheep adjusted to the site.

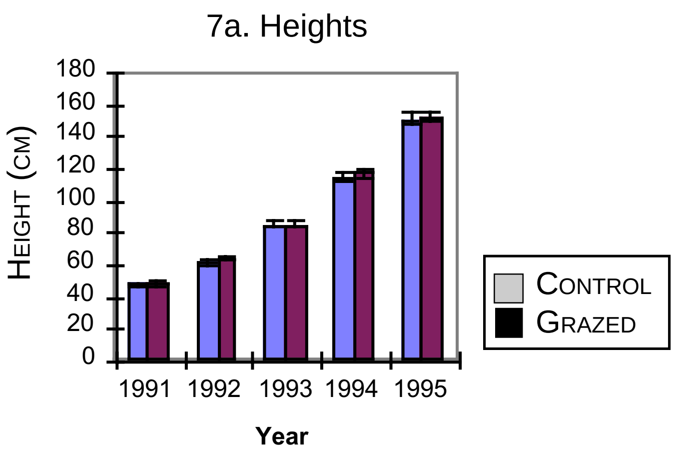
Seedling responses

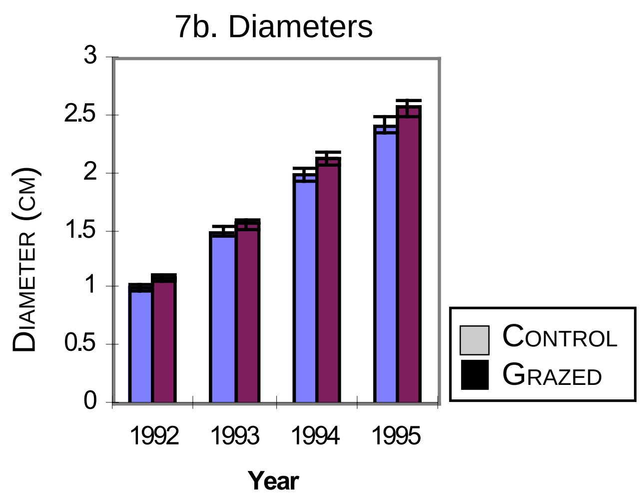
Black spruce seedling initial heights (1991) were similar between control (mean height=47.4 cm) and treatment (mean height=47.8 cm) plots (Figure 7a, ANOVA, F-ratio=0.8, p=0.8). Heights were similar between grazed and control plots in all survey years (Figure 7a, ANOVA, F-ratio=0.32, p=0.6). Diameter and volume growth also showed a lack of response to grazing (Figure 7b, diameters, ANOVA, F-ratio=0.85, p=0.4; Figure 7c, volumes, ANOVA, F-ratio=1.10, p=0.13). Seedling survival was lower compared to jack pine (79.2 percent for the control plots and 85.6 percent for the grazed plots), but was not affected by grazing (T-test, p=0.5).

Vegetation responses

Competing woody species selected for height responses to grazing include balsam fir (*Abies balsamea*), trembling aspen, white birch, blueberry, pin cherry, mountain-ash, raspberry, black spruce (natural regeneration), serviceberry (*Amelanchier* spp.) and willow. Initial heights of these species did not differ between control and treatment plots (Table 4, ANOVA, $p>0.05$). Grazing reduced heights of mountain-ash and raspberry and slowed height growth of pin cherry and black spruce (Table 4, ANOVA, $p<0.05$). Height reduction of black spruce may be due to chance, as the p value was weak (p=0.04), and no damage was noted on crop tree seedlings due to grazing. Sheep do not prefer spruce (Newsome 1993). After two growing seasons, heights were significantly shorter in grazed plots compared to control plots for willow (ANOVA, F-ratio=18.74, p=0.01), black spruce (ANOVA, F-ratio=8.71, p=0.04) and mountain-ash (Table 4, ANOVA, F-ratio=69.2, p=0.01).

No treatment effects were noted in percent cover for any vegetation class between control and grazed blocks for any survey time (initial, postgraze or final, Table 5). After two years broadleaf herb and herbaceous percent cover had significantly increased in the control plots (Table 5, T-test, T-statistic >9.6, $p \leq 0.001$). Broadleaf herb cover had also increased in the grazed plots (T-test, T-statistic=2.88, p=0.045.)





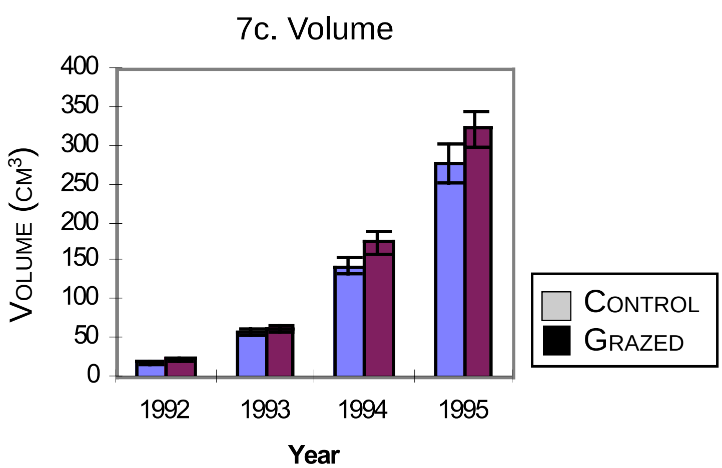


Figure 7. The Mortimer trial crop tree responses by year; (a) heights (b) diameters (c) Volumes. Diameters were not recorded in 1991.

Table 4. Mean heights (± S.E.) (cm) of competing woody species by treatment and survey period at the Mortimer trial site.

Species and Treatment	Initial June 1992			Postgraze September 1992			Final August 1994		
	n	Height	S.E.	n	Height	S.E.	n	Height	S.E.
Balsam fir									
Control	5	54.7	10.9	5	65.1	6.3	5	90.5	7.4
Grazed	5	50.3	2.7	4	59.7	4.8	5	116.5	5.3
Black spruce									
Control	5	40.6	6.2	5	50.9	5.6	5	107.2	6
Grazed	5	35.6	2.6	4	43.3	4.2	5	82.5	5
Blueberry									
Control	5	16.6	1.9	4	18.4	3.7	3	32.9	3.9
Grazed	5	21.8	3.5	4	20.8	1.1	3	26.7	4
Mountain-ash									
Control	3	104.9	5.4	3	100.7	15.3	3	135.3	12.4
Grazed	5	104.6	7.4	4	96	8.7	5	98.6	27.3
Pin cherry									
Control	5	102.6	7.8	5	123.1	13.8	5	129.3	15.8
Grazed	5	94.6	14.6	4	100.6	9.8	4	104.6	9.9
Raspberry									
Control	5	42.7	6.4	5	42	3.6	5	57.2	2.3
Grazed	5	41.2	4.8	4	33	5.5	5	43.1	4.2
Serviceberry									
Control	4	46.6	13.8	3	64.7	14.3	2	84.4	4.3
Grazed	4	55	3.2	2	55	5	4	70.2	9
Trembling aspen									
Control	5	57.8	6.8	5	69.3	11.6	5	109.8	8.7
Grazed	5	53.9	7.3	4	68.6	16.1	5	88.3	24.1
White birch									
Control	5	80.1	10.9	5	81.3	5.4	5	134.7	14.6
Grazed	5	74.5	4.3	4	76.9	2.4	5	108.3	6.1
Willow									
Control	5	48.7	8.6	5	63.7	11.9	5	94.5	13.8
Grazed	5	55.2	7.9	4	63.2	14.8	5	51.4	7.7

TABLE 5. MEAN PERCENT COVER (± S.E.) BY TREATMENT AND SURVEY PERIOD FOR SEVEN VEGETATION CLASSES AT THE MORTIMER TRIAL SITE.

VEGETATION CLASS	INITIAL JULY 1992		POSTGRAZE SEPTEMBER 1992		FINAL AUGUST 1994	
	HEIGHT	S.E.	HEIGHT	S.E.	HEIGHT	S.E.
TREES						
CONTROL	7.18	0.5	5.91	1.2	9.04	1.4
GRAZED	7.34	1.6	4.78	0.6	7.96	1.6
SHRUBS						
CONTROL	24.38	5.6	22.76	6.5	23.99	3.9
GRAZED	29.05	7.7	11.09	5.5	36.1	9.4
BROADLEAF HERBS						
CONTROL	12.56	2.2	10.82	3.3	30.33	1.3
GRAZED	14.07	3.1	4.76	1.1	32.52	5.6
GRAMINOIDS						
CONTROL	26.85	6.2	18.64	4.2	28.43	5.6
GRAZED	31.77	7.5	15.21	3.5	24.47	5.8
WOODY						
CONTROL	31.68	5.4	33.66	6.1	3.02	5.1
GRASSES	36.39	8.3	15.88	5.4	44.17	10.1
HERBACEOUS						
CONTROL	39.4	6.7	29.47	6	58.76	6.5
GRAZED	45.83	8.9	19.97	4.2	39.71	8.1
TOTAL COVER						
CONTROL	70.76	10.9	63.12	11.7	91.79	4.4
GRAZED	82.22	16.9	35.85	9.1	101.16	7

THE SILK TRIAL

SEEDLING RESPONSES

Jack pine seedlings in this trial did show differences in seedling height, diameter and volume growth between control and treated plots during the three-year survey period. There were no initial differences between treated and control seedlings in height (Figure 8a, d.f.=9, ANOVA, F-ratio=6.68, p=0.06), diameter (Figure 8b, ANOVA, d.f.=9, F-ratio=0.13, p=0.7) or volume (Figure 8c, ANOVA, d.f.=9, F-ratio=0.15, p=0.7). The following year control seedlings were significantly taller (Figure 8a, ANOVA, d.f.=9, F-ratio=175.15, p=0.0002), greater in diameter (Figure 8b, ANOVA, d.f.=9, F-ratio=50.29, p=0.002), and volume (Figure 8c, ANOVA, d.f.=9, F-ratio=35.31, p=0.004) than the treated seedlings. By the third growing season, the treated seedlings had increased their growth rate. There was no longer any significant difference between grazed and control seedlings for height (Figure 8a, ANOVA, d.f.=9, F-ratio=0.44, p=0.55), diameter (Figure 8b, ANOVA, d.f.=9, F-ratio=0.85, p=0.4) or volume (Figure 8c, ANOVA, d.f.=9, F-ratio=0.35, p=0.3). Seedling survival was high (91 percent after three years), and was not affected by grazing (T-test, p=1).

VEGETATION RESPONSES

Woody species tested for height responses to grazing include white birch, trembling aspen, beaked hazel (*Corylus cornuta*), pin cherry, mountain maple (*Acer*

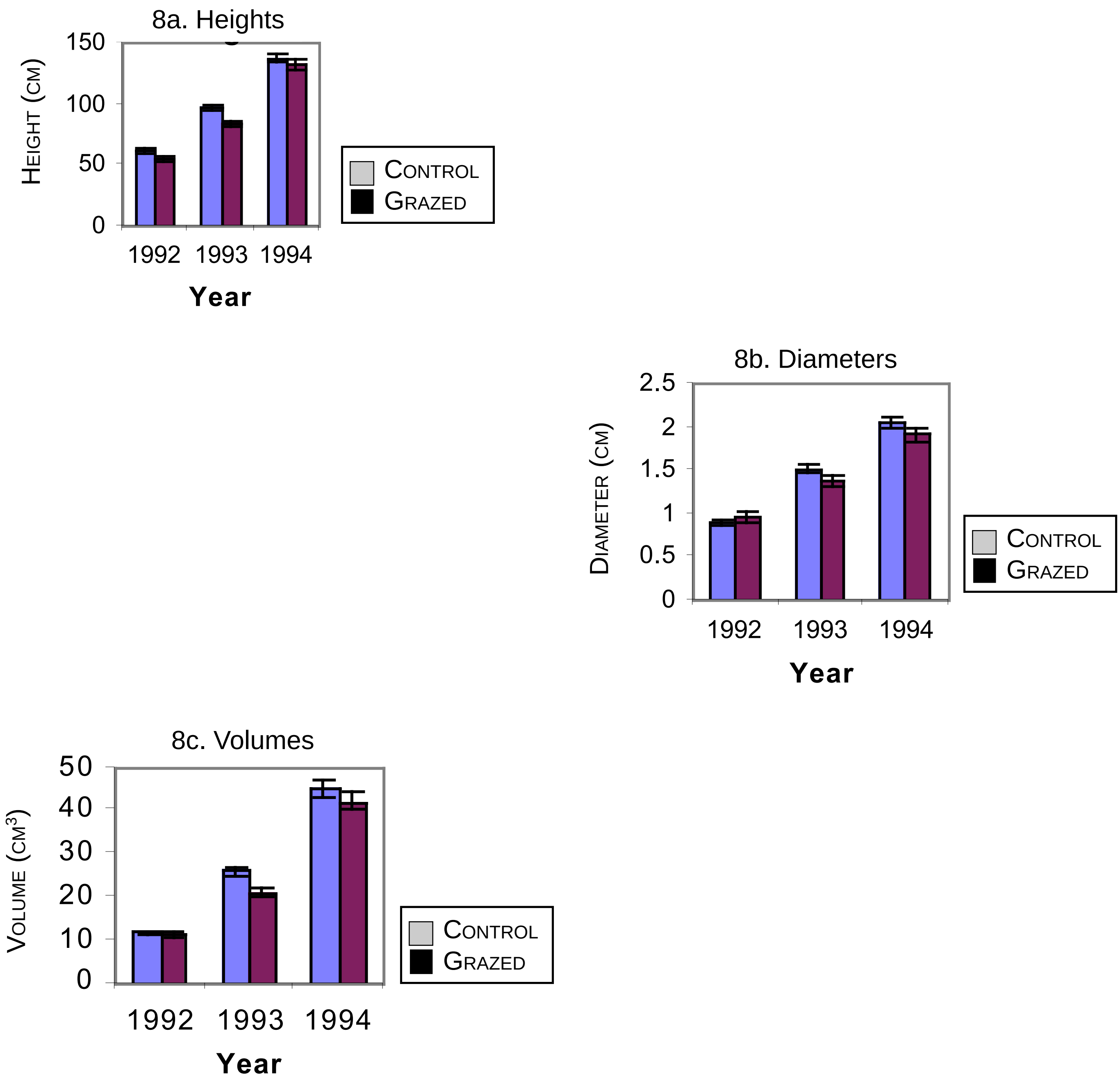


Figure 8. Silk trial crop tree responses by year; (a) height, (b) diameter and (c) volume.

spicatum), wild red raspberry, alder (*Alnus* spp.) and willow. Initial heights of these species did not differ between control and treatment plots (Table 6, ANOVA, F-ratio<5.66, p>0.07). Pin cherry heights were significantly reduced by grazing (ANOVA, F-ratio=10.61, p=0.047), but recovered after two years (ANOVA, F-ratio=2.35, p=0.2). Mountain maple and willow were significantly taller in control plots compared to grazed plots two years after grazing (Table 6, mountain maple, ANOVA, F-ratio=14.9, p=0.03; willow, ANOVA, F-ratio = 24.4, p=0.008). The other species did not show a response to grazing.

Percent cover for any of the vegetation classes did not differ between control and treatment plots before grazing (Table 7, ANOVA, F-ratio<3.5, p>0.1). Grazing significantly reduced percent cover in all classes except trees and graminoids (Table 7, ANOVA, F-ratio>13.3, p≤ 0.02). Total cover after grazing was 25.7 percent in the grazed plots compared to 78.5 percent in the control plots. After two growing seasons the grazed plots showed a complete recovery, as no differences were noted in percent cover for any vegetation class between control and grazed plots (Table 7, ANOVA, F-ratio< 5.37, p>0.07). Grazing appears to have promoted an increase in shrub, woody and total cover after two years (T-test, T-statistic >2.8, p<0.05). In the control plots, graminoid cover decreased between initial and final surveys (T-test, T-statistic =3.89, p=0.018).

Table 6. Mean heights (± S.E.) (cm) of competing woody species by treatment and survey period at the Silk trial site.

Species and treatment	Initial June 1992			Postgraze September 1992			Final August 1994		
	n	Mean	S.E.	n	Mean	S.E.	n	Mean	S.E.
Alder									
Control	1	90	0	3	46.7	27.2	5	85.6	6
Grazed	1	70	0	3	119.4	30.9	5	66.5	11.2
Beaked hazel									
Control	5	63	4.9	4	63.8	4.6	1	103.7	0
Grazed	5	55.5	4.8	4	59.1	7.3	1	90	0
Mountain maple									
Control	5	37.6	2.6	4	49.2	5.1	5	62.9	4.6
Grazed	5	29.3	7.9	5	63.1	14.6	4	54.4	6.4
Pin cherry									
Control	5	92	2.5	4	107.7	4.7	5	131	8
Grazed	5	77	4.1	5	88.4	6.8	5	101.2	13.5
Raspberry									
Control	5	35.7	5.5	4	41.9	6.1	5	49.7	2.4
Grazed	5	37.8	3.6	5	30.6	2.9	5	42.5	5.8
Poplar									
Control	5	109.2	9.7	4	115.8	12.2	5	194	15.3
Grazed	5	102.3	5.9	5	101.7	7.3	5	190.8	20
White Birch									
Control	5	37.2	4.8	4	44.9	3.2	5	105.9	6.7
Grazed	5	47.1	4.6	5	44.9	4.4	5	73.5	10.3
Willow									
Control	5	54.2	4.9	4	60.2	4.9	5	107.8	8.5
Grazed	5	53.6	4.1	5	52.3	3.4	5	88.4	8.1

Table 7. Mean percent cover (± S.E.) by treatment and survey period for seven vegetation classes at the Silk trial site.

Vegetation Class	Initial July 1992				Postgraze September 1992				Final August 1994			
	control	S.E.	grazed	S.E.	control	S.E.	grazed	S.E.	control	S.E.	grazed	S.E.
Trees	21.8	7.4	19.7	5.1	20.2	5.6	11.1	2.4	26.1	5.6	22.4	3.7
Shrubs	28.1	3.6	23.5	2.3	31.3	2.1	6.4	3.1	45.6	8.8	39.2	3.8
Broadleaf herbs	29.1	7.2	27.5	5.2	19.2	4.4	4.2	0.9	49	3.4	38	1.6
Graminoids	9.8	1.6	9.4	3.5	7.9	3.8	4	2.2	6.9	1.4	13.5	5.7
Woody	49.2	10.4	43.2	7	51.4	6.7	17.5	4.1	71.6	8.9	61.6	3.5
Herbaceous	38.9	6.7	36.9	5.3	27	6.3	8.2	3	55.9	4.6	51.6	4.9
Total cover	88.1	16.5	80.1	8.6	78.5	10.5	25.7	6.2	127.6	9.3	113.1	4.1

The Gibson Lake Road Trial

Seedling responses

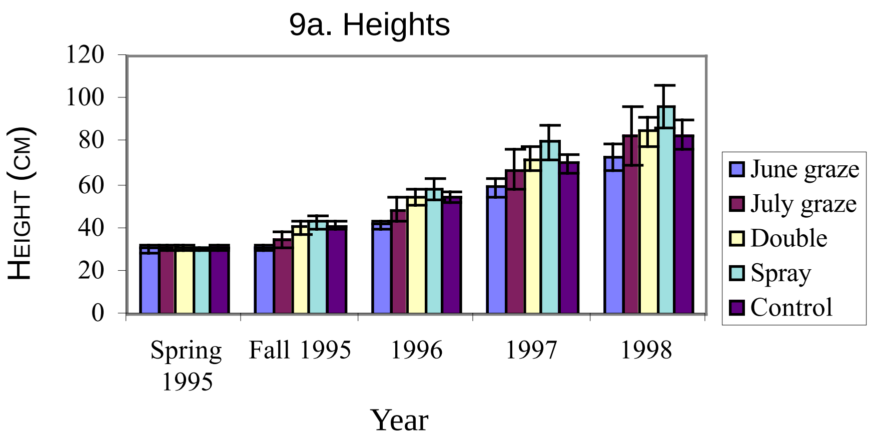
The white spruce seedlings showed no height growth response to the different treatments by the third post-treatment growing season (1998). There were no initial height differences between the various treatments (Figure 9a, Table 18, ANOVA, F-ratio=0.04, p=1.0). The least amount of growth was for the seedlings in the June graze plots (Figure 9a, mean heigh=73.2 ± 6.5 cm), while the greatest growth was for the seedlings in the chemically tended plots (Figure 9a, mean height=96.5 ± 10.1 cm). This could suggest that July grazing is better than June, and more frequent grazing is better than a single graze. The chemical treatment could be better than grazing because the tallest seedlings were in the chemical treatment plots, suggesting that this method is better than grazing for controlling competition. However, the lack of significant differences makes any of these conclusions tentative. Seedling diameters showed a significant treatment response by 1998 (Figure 9b, ANOVA, F-ratio=3.97, p=0.035). Seedlings in the spray blocks had significantly larger diameters (mean = 17.4 mm) than in any other treatment blocks except for the July graze (which did not differ). Seedling volumes did not show a significant treatment response by 1998 (Figure 9c, p>0.05). Seedling survival was good, ranging from 87.7 percent for the July graze plots to 91.6 percent for the herbicide treatment sites, but was not affected by any of the treatments (ANOVA, p>0.1).

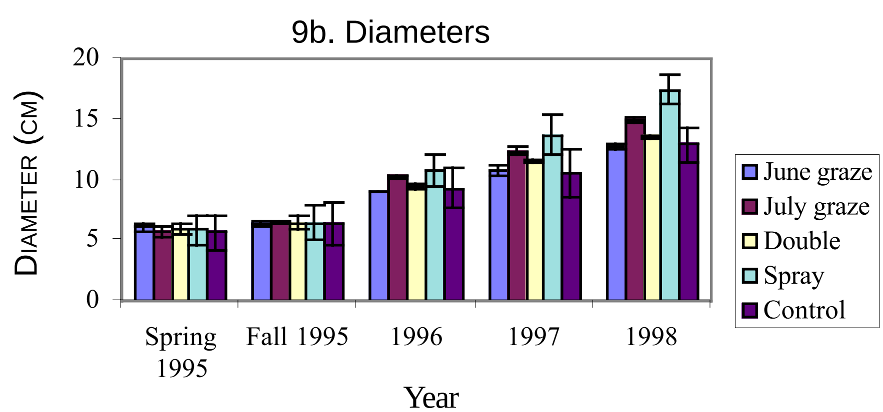
Ecosite significantly affected spruce height growth (Figure 10, ANOVA, F-ratio > 8, p<0.02). Spruce growing on the richer, conifer mixedwood ecosite (3b) were taller than those on the more exposed, drier, jack pine ecosite (2a).

Vegetation responses

Competing tree species investigated for height responses to treatment effects were white birch, trembling aspen and jack pine. Jack pine and aspen had no initial height differences between treatments (Table 8, ANOVA, F-ratio<0.8, p=0.6). White birch were shorter in the control and chemical tending plots compared to the double grazed plots (ANOVA, F-ratio=4.36, p=0.027).

No treatment effects were evident in aspen and white birch heights one season after treatment (Table 8, aspen, ANOVA, F-ratio=1.03, p=0.4; white birch, ANOVA, F-ratio=1.29, p=0.35). Jack pine had a negative response to grazing (Table 19, ANOVA, F-ratio=8.44, p=0.004), as they were significantly shorter in the single





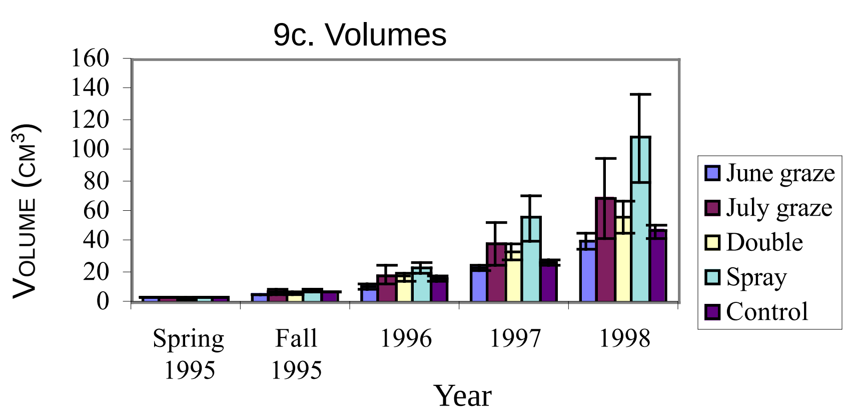


Figure 9. Gibson Lake Road trial crop tree responses by treatment and year; (a) heights (b) diameters and (c) volumes N=3 for each treatment.

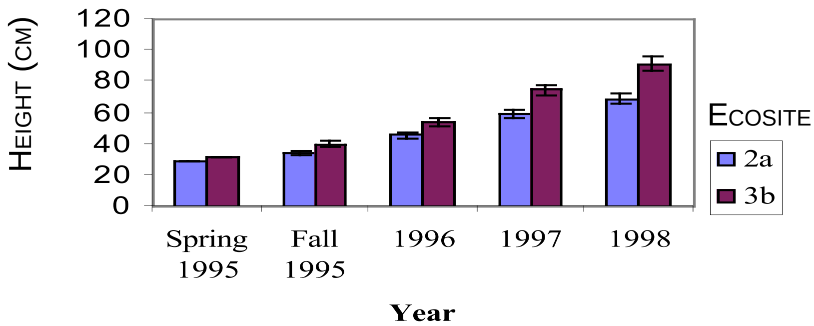


Figure 10. Gibson Lake Road Trial crop tree heights by ecosite.

grazing plots compared to the other treatments, probably from nipping by sheep. Treatment effects were not evident three years after treatment (Table 8, p>0.05).

Shrub species selected for treatment effects on height growth include bush honeysuckle, blueberry, pin cherry, wild red raspberry, serviceberry, sweetfern (*Comptonia peregrina*) and willow. These species showed no treatment effects on height growth for any survey (Table 8, p>0.05).

Treatment effects were noted for percent cover after one season for shrubs, graminoids, woody and total cover classes (Table 9). Shrub cover was least in the sprayed plots. The single grazed plots were similar to each other, but shrub cover in the July grazed plots was significantly less than in the double graze and control plots (which were similar). Graminoid cover in the three grazing treatment plots was significantly less than in the chemical spray and control plots. Woody cover was significantly less in the chemical spray plots than in all other plots (which did not differ from each other). Total cover was least in the chemical spray plots, significantly less than for all other treatments except for the July graze plots. Total cover was greatest in the control plots, significantly greater than for all other treatments except for the double grazed plots. Total percent cover was similar among the three grazing treatments, with the only significant difference being reduced total cover in the July graze plots compared to the double graze plots.

After three years, treatment effects on vegetative cover were only evident for shrub cover (ANOVA, d.f.=14, F-ratio=7.95, p=0.004). Shrub cover was least in the herbicide sprayed plots (25.1 percent), significantly less than the other treatments but similar to the July grazed plots (42.9 percent) (Table 9). Shrub cover in all of the grazed plots had recovered after three years so that it did not differ from the control plots. No treatment effects were noted in the other vegetation classes.

Ecosite effects were noted for tree percent cover by 1998 (ANOVA, d.f.=14, F-ratio=8.35, p=0.018), with less tree cover on the jack pine ecosite compared to the conifer mixedwood ecosite. Ecosite also influenced total cover by the same time (ANOVA, F-ratio=5.35, p=0.046).

Although increases occurred for almost all classes and treatments between pre-treatment and final surveys, not all increases were significant (Table 9, p<0.05). Tree cover and graminoid cover did not change significantly for any treatment over this period. Shrub cover increased significantly for the June grazed and double grazed plots. Broadleaf herbs and herbaceous classes increased significantly for the double

Table 8. Mean heights (± S.E.)(cm) by treatment class and survey period for competing woody species at the Gibson Lake Road trial site.

Species and treatment	Initial June 1995			Postgraze August 1996			Final August 1998		
	n	Mean	S.E.	n	Mean	S.E.	n	Mean	S.E.
Blueberry									
June graze	3	15	0	3	17	0.1	3	24.5	1.9
July graze	3	19.7	0.9	3	16.4	0.7	3	23.9	1
Double graze	3	17.4	0.6	3	19.3	1.6	3	25.5	2.2
Chemical spray	3	15	0.3	3	18.5	1.3	3	23.9	1.2
Control	3	16.3	0.3	3	20.4	1.1	3	27.6	2.8
Bush honeysuckle									
June graze	3	32.8	5.7	3	28.9	2.2	2	29.6	4
July graze	3	19.8	5.9	2	25.2	1.6	3	30.6	2.5
Double graze	2	32.5	2.5	3	26.1	2.2	3	31.4	3.4
Chemical spray	3	26	1.5	3	24.6	1.9	3	27.2	0.96
Control	3	23.5	2.5	3	29.4	2.7	3	27.9	5
Jack pine									
June graze	3	24.3	4.4	2	15.7	5.8	3	37.1	5.6
July graze	3	33.7	13.2	3	13.3	3.7	3	37.6	9.1
Double graze	3	20	2.5	3	26.6	7.9	3	127	50.9
Chemical spray	3	21.3	0.9	3	46.9	5.8	3	106.9	19.8
Control	3	21.3	0.7	3	47	3.4	3	114.8	11.2
Pin cherry									
June graze	3	68.8	9.2	3	86.8	5.2	3	119.7	9.6
July graze	3	62.2	3.8	3	61.6	3.7	3	89.8	11.7
Double graze	3	74.2	4.5	3	94.5	5.4	3	128.8	14.1
Chemical spray	3	66.5	4.4	3	71.6	3.8	3	96.5	8.7
Control	3	67.3	4.1	3	100.5	2.4	3	138.8	11.7
Serviceberry									
June graze	3	54.4	4.4	3	55.2	3	3	72	10.2
July graze	3	55.7	5.2	3	57.3	6.6	3	72.9	8.8
Double graze	3	64.3	13.1	3	70.4	7.1	3	82.6	7.7
Chemical spray	3	50.7	7.2	3	53.4	2.7	3	72.2	1.9
Control	3	44	5.3	3	54.7	7.3	3	73.2	17
Sweetfern									
June graze	3	24.6	4.8	3	30.9	1.5	3	40.5	2.6
July graze	3	22.8	4	3	31.2	1.1	3	38.9	2.1
Double graze	3	28.3	1.4	3	36.1	1.9	3	45.5	2.8
Chemical spray	3	21.2	0.4	3	25.8	3.4	3	38.9	2.7
Control	3	23.2	6.6	3	32.5	0.6	3	44.2	2.8
Trembling aspen									
June graze	3	82.8	7.3	3	120.2	16.1	3	202.6	52.3
July graze	3	84.7	5	3	126	28.1	3	230.8	76.2
Double graze	2	90	8	2	150.8	10.9	2	290.1	18.6
Chemical spray	3	91.3	7.2	3	124	13.9	3	166	21.3
Control	3	108.3	21.7	3	179	37.2	3	299	45.6
White Birch									
June graze	3	57.7	1.5	3	93	18.9	3	136	23.8
July graze	3	57.7	14.3	2	74.6	34	3	178.3	65.7
Double graze	3	83.3	8.1	3	112.2	25.2	3	195.3	18.3
Chemical spray	3	67	10.4	2	46.4	16.4	3	82.6	21.1
Control	3	32.7	2.6	3	79.2	2.7	3	168.6	41
Willow									
June graze	3	109.2	7.3	3	103.2	4.9	3	135.5	1.1
July graze	3	87	12.5	3	122.6	13.7	3	130.9	19.2
Double graze	3	120.5	6.3	3	139.2	4	3	161.1	13.6
Chemical spray	3	86	9.1	3	111.4	19.1	3	127.7	19.1
Control	3	91.3	9.6	3	127.3	7.7	3	155.6	15

grazed, herbicide spray and control plots. Woody cover increased significantly for the double grazed plots. Total cover was significantly increased in the double grazed and control plots.

Vegetation Changes Summary

When comparing the three study sites with the same experimental layout (graze and control), changes between initial and final percent cover of vegetation classes are not consistent across all three sites. Changes are not consistent between control and grazed sites either. The percent tree cover did not change for any site except for an increase in the percent tree cover on the Mortimer grazed plots. Changes in the percent shrub cover were more variable. It did not change in any control plots, but on the grazed plots the percent cover increased in Silk, remained the same in Mortimer, and decreased in Chappise. Broadleaf herb percent cover increased with or without grazing on Mortimer and Chappise, but did not change on Silk. Graminoid percent cover did not change on any site, but did decrease on the Silk control plots.

Woody cover (trees and shrubs) increased on the Chappise and Silk control plots, but remained the same on Mortimer. On the grazed sites, the percent woody cover increased on Silk, did not change on Mortimer, and decreased on Chappise. Herbaceous cover (grasses and broadleaf herbs) increased on all sites, except a decrease on the Chappise grazed sites and no change on the Silk control sites.

The total percent cover of all vegetation increased, with or without grazing, on all sites except for a decrease on the Chappise grazed plots. A single season of grazing temporarily decreased the percent vegetative cover. The vegetation quickly rebounded and grazed sites were comparable to control sites in percent cover and composition.

Discussion and Recommendations

Tree response to grazing

One of the objectives of these trials was to determine the response of tree seedlings to grazing. A comparison of the growth and survival of tree seedlings between grazed and control blocks found that seedlings in these trials generally did not show a response to grazing with improved growth. Other studies have shown no response to grazing using Douglas-fir (Allen and Bartolome 1989, Bancroft 1992b), Ponderosa pine (McDonald and Fiddler 1987), or western red cedar (Lousier 1990) as the crop species. Fiddler and McDonald (1991) found that nine years of grazing was ineffective for releasing Jeffrey pine (*Pinus jeffreyi)* seedlings, as enough vegetation remained after grazing to prevent conifer release. There have not been any studies that used black spruce or jack pine as the crop species. Studies with white spruce found no height response to grazing, either from one (Bancroft 1992b, Negrave 1993), two (Bancroft 1992a) or five seasons (Sutherland *et al.* 1991). White spruce root collar diameter did respond to grazing after two (Bancroft 1992a) and five seasons (Sutherland *et al.* 1991).

Crop tree response to grazing is variable, and that at least two years are needed after initial treatment before seedlings show a significant response (Erickson 1992, Hays 1994). Generally, up to five years are needed for a significant crop tree response (F.W. Bell, pers. comm.).

Table 9. Mean percent cover (± S.E.) for seven vegetation classes by treatment and survey period at the Gibson Lake Road trial site.

	Initial June 1995		Postgraze August 1996		Final August 1998	
Vegetation class	Mean	S.E.	Mean	S.E.	Mean	S.E.
Trees						
June graze	11	5.1	6.2	2.5	13.5	7.1
July graze	9	2.9	8.7	4.7	18.8	9.9
Double graze	8.3	4.1	6.7	3.2	16.3	7.8
Chemical spray	9.8	0.35	5.2	1.7	9.6	1.3
Control	5.7	2.1	8.5	5.4	16.4	9.6
Shrubs						
June graze	30.7	8.2	27.2	2.9	59.7	2.9
July graze	46.2	9.2	21	2.4	42.9	11
Double graze	43.5	4.3	31	1.1	70.6	4
Chemical spray	38	19.1	8.2	3.8	25.1	1.5
Control	33	10.7	31	2.3	68.6	9.2
Broadleaf herbs						
June graze	10	6.2	14	2.3	29.5	9.6
July graze	11.8	2.7	11.1	6	25.2	13.2
Double graze	8.9	4.3	16.9	5.4	34.5	3.5
Chemical spray	11.9	2.6	11.4	2.8	33.9	5.3
Control	11.7	2.9	21.5	4.9	44.4	2.6
Graminoids						
June graze	8.1	1.4	3.7	0.4	13.6	5
July graze	8.4	3.4	3.3	0.9	8.3	5.7
Double graze	7.6	2.9	2.5	0.4	5.3	1.1
Chemical spray	10.9	7.5	7.9	1.6	18	5.8
Control	5.4	1.8	6.2	1.1	7.6	0.8
Woody						
June graze	41.7	12.7	33.5	3	73.2	9.9
July graze	55.2	9.8	29.7	2.7	61.7	20.9
Double graze	51.8	7.6	37.6	3.8	86.9	9.8
Chemical spray	47.8	18.96	13.4	2.1	34.7	0.8
Control	38.7	11.5	39.5	7.6	85	18.4
Herbaceous						
June graze	18.1	6.2	17.9	2.3	43.1	7.9
July graze	20.2	2.4	14.3	5.2	33.5	9.6
Double graze	16.5	7.2	19	5.1	39.9	2.7
Chemical spray	22.9	9.7	19.4	2.2	51.9	0.6
Control	17.1	4.4	26.5	4.2	52	2.8
Total cover						
June graze	59.8	18.8	50.9	4.6	116.3	17.2
July graze	75.4	12	43.9	5.7	95.2	22.8
Double graze	68.3	14.8	56.2	3.5	126.7	9.8
Chemical spray	70.6	28.7	36.4	3.6	86.6	0.8
Control	55.8	15.8	65.1	4.7	136.9	17

Several reasons may exist for the lack of tree response to grazing in these trials. These would include:

- Duration of grazing - Vegetation can quickly recover within one to two years after only one season of grazing, with no noticeable differences between grazed and ungrazed plots. Vegetation recovered after one season in a B.C. study (Bancroft 1992b), and even after one grazing pass, requiring a second pass (Bancroft 1991).
- Size of competition - Competing trees and shrubs over 1 m tall would have been out of the reach of sheep and could avoid substantial loss of foliage and branches (Tweedhope 1985). Shrubs tend to have little height reduction from grazing (Bancroft 1992a).
- Root competition - Even though aboveground competing vegetation is reduced, root competition would still take place (McDonald and Fiddler 1987). Root systems of grazed plants would be intact, and could sequester resources such as moisture and nutrients from the crop trees, despite a reduction in competitor leaf area (McDonald 1986). Root removal increased Ponderosa pine growth (McDonald and Fiddler 1987).

At the Silk Township site, jack pine showed a negative response to grazing, with reduced seedling growth in treated plots compared to control plots in the first post-survey year. Several factors may help to explain this difference. Browse damage from sheep may have reduced seedling heights. Control seedlings may have grown at a greater height growth rate as a response to moderate competition. The grazed seedlings would have had reduced competition and not been forced to grow at a greater rate to escape the competition. The decrease in grass cover over time is probably due to increases in cover of other classes and exclusion of grasses.

Sheep damage to crop trees

We also wanted to know if sheep would damage conifer seedlings. We found a low incidence of browse damage to the trees, particularly jack pine, but was not statistically analysed. From the literature, it is evident that browsing by sheep is most likely to occur shortly after budbreak and before the new growth has hardened off (Leininger and Sharrow 1989, Lousier and Lousier 1991, Bancroft 1992b). At this time the growth is palatable and sheep may eat it. Grazing in plantations is not recommended during this time. Sheep will also eat conifers when they have little available palatable forage. Physical damage is minimized by not concentrating the sheep in one area or herding them along the same paths all the time. Flock control needs to be considered to accomplish this. (Doescher *et al*. 1987, Pickering and Richard 1992, Newsome 1993).

Weight gain in sheep

The third objective was to determine whether sheep can gain adequate weight on plantations. We found that sheep did not have the same weight gain on the plantation areas as they did on the pasture after the Mortimer and Silk trials. Sheep lost weight in another study, primarily due to lactation (Leininger *et al*.1989). General observations by a veterinarian on sheep from the Edwards trial rated the sheep in poorer condition after the trial compared to before the trial. It appears that there is inadequate forage for sheep compared to a pasture, and this would not be a recommendation for sheep grazing to control vegetation, especially if one of the objectives was for the sheep to gain weight during the trial. Grasses have been sown on some sites to provide adequate forage for livestock, as most forest vegetation is unpalatable to livestock (Karl and Doescher 1993). If grasses and other more palatable species were on a site, such as an old field site, then sheep would probably be ideal for vegetation control.

Vegetation response to grazing

The fourth objective was to determine whether sheep would selectively eat competing vegetation. Even though sheep will eat competing vegetation, they did not reduce heights of most of the woody species after grazing, and other studies have had similar results (Lousier 1990, Bancroft 1992a). Height reductions in shrubs were noted in other studies (McDonald and Fiddler 1987, Negrave 1993). Repeated grazing would reduce growth and nutrient reserves of trees and shrubs (Harper 1977) and allow the crop trees to outcompete them. Some height reductions were noted in this study. Raspberry height was reduced in the Mortimer trial from both grazing and trampling. Raspberry is not favoured by sheep (Sutherland 1986, Newsome 1993), but can quickly recover from grazing by sprouting new shoots from the rootstock the following year. Grazing reduced heights of mountain-ash in the Mortimer trial, and it may be more sensitive to damage. It is unknown why black spruce and willow heights were reduced.

Vegetation can respond quickly to grazing damage, with rapid regrowth to replace losses (Bancroft 1991). Plants can move in and occupy vacant areas by seed dispersal or clonal growth (Harper 1977, Sutherland *et al.* 1991). Grazing can also promote grass growth, as it is tolerant of grazing (McDonald 1986).

Sheep grazing as an alternative to herbicides

Based on the results of these trials, sheep grazing is not a practical, wide scale alternative to herbicide use for vegetation control in northeastern Ontario. Crop trees did not show a definite response to grazing in most cases. Unfortunately, since none of the treatments continued for more than one season, we do not know if a longer grazing period would significantly influence crop tree growth, or if differences in growth take longer than three years to become evident. We estimate that the operational cost of using sheep would be two to four times greater than for chemical tending. The experimental costs of these trials are not valid for estimating actual grazing costs per hectare.

A major economic factor influencing the use of sheep in northeastern Ontario is the distance needed to transport sheep to the sites. Unlike British Columbia, rangeland is not in demand in northern Ontario. Grazing also needs to occur for more than one season, until the seedlings are free to grow. The quick recovery of grazed vegetation may mitigate any crop tree gains from grazing.

Foster (1998) and Pickering and Richard (1993) provide excellent reviews of the use of grazing animals for forest vegetation management and factors involved with selecting this as an option. Both papers provides an extensive review of factors to consider, such as site assessment, grazer selection, management considerations in planning, implementation and monitoring of a grazing program. Managers considering sheep grazing for vegetation control should also consult these papers in combination with the experimental results given here.

Appendices

Appendix 1. Analysis of variance results for seedling heights for Chappise, Silk and Mortimer sheep grazing trials by year. Significant p-values are in bold. Degrees of freedom are 9 for Silk and Mortimer sites, and 11 for Chappise.

	Chappise		Silk		Mortimer	
Year	F-ratio	P-value	F-ratio	P-value	F-ratio	P-value
1991	1.69	0.25			0.08	0.8
1992	1.49	0.3	6.68	0.06	0.29	0.6
1993	0.08	0.8	175.1	**0.0002**	0.1	0.8
1994			0.4	0.5	0.38	0.6
1995					0.32	0.6

Appendix 2. Analysis of variance results for block and treatment effects on height growth of competing woody species at the Chappise trial site. Significant p-values are in bold.

Species	Initial June 1991		Postgraze September 1991		Final August 1992	
	Block	Treatment	Block	Treatment	Block	Treatment
Blueberry						
F-ratio	1.54	0.81	1.05	1.18	7.42	0.58
P-value	0.34	0.4	0.5	0.3	**0.02**	0.5
Bush honeysuckle						
F-ratio	1.74	4.38	91.1	3.3	2.94	0.02
P-value	0.5	0.3	**0.01**	0.21	0.2	0.9
Jack pine						
F-ratio	4.5	3.27	3.23	1.4	8.2	1
P-value	0.1	0.17	0.25	0.4	0.1	0.4
Labrador-tea						
F-ratio	2.55	0.87	3.11	0.03	3.48	4
P-value	0.3	0.46	0.26	0.9	0.2	0.2
Pin cherry						
F-ratio	1.43	0.04	2.36	0.27	4.73	1.25
P-value	0.4	0.8	0.2	0.6	0.08	0.3
Mountain-ash						
F-ratio	2.49	2.2	0.78	0.08	9.1	0.4
P-value	0.3	0.3	0.6	0.8	0.0501	0.4
Raspberry						
F-ratio	0.56	0.29	0.17	0.61	16.65	0.97
P-value	0.7	0.6	0.96	0.5	**0.004**	0.4
Skunk currant						
F-ratio	0.68	1.68	0.66	0.33	3.21	0.15
P-value	0.7	0.3	0.7	0.6	0.14	0.7
Trembling aspen						
F-ratio	2.04	0.4	1.79	17.1	6.4	2.03
P-value	0.3	0.6	0.3	**0.01**	**0.03**	0.2
White Birch						
F-ratio	12.7	1.96	6.74	2.86	1.37	0.18
P-value	0.2	0.4	0.13	0.23	0.38	0.7
Willow						
F-ratio	0.81	0.04	0.58	0.16	1.03	0.13
P-value	0.6	0.8	0.7	0.7	0.5	0.7

Appendix 3. Analysis of variance results for treatment effects on percent cover of seven vegetation classes for three measurement periods at the Chappise trial site. Significant p-values are in bold.

	Initial June 1991		Postgraze September 1991		Final August 1992	
Year	F-ratio	P-value	F-ratio	P-value	F-ratio	P-value
Trees	**7.98**	**0.037**	4.15	0.097	1.22	0.32
Shrubs	**14.75**	**0.012**	1.63	0.3	**10.9**	**0.022**
Broadleaf herbs	**20.55**	**0.006**	0.53	0.5	1.58	0.3
Graminoids	0.67	0.5	0.037	0.9	3.58	0.12
Woody	**16.49**	**0.0097**	4.19	0.096	**8.8**	**0.03**
Herbaceous	**11.45**	**0.02**	0.34	0.6	3.77	0.1
Total	**18.16**	**0.008**	2.26	0.2	0.93	0.4

Appendix 4. T-test results for percent cover changes in control and grazed plots for seven vegetation classes between initial and final surveys at the Chappise trial site. Significant p-values are in bold.

Vegetation class	Control		Grazed	
	T-statistic	P-value	T-statistic	P-value
Trees	2.4	0.06	0.44	0.68
Shrubs	0.74	0.5	8.54	**<0.001**
Broadleaf herbs	1.34	0.24	4.12	**0.009**
Graminoids	1.43	0.2	2.35	0.066
Woody	1.45	0.2	6.47	**0.001**
Herbaceous	1.67	0.2	5.88	**0.002**
Total cover	0.21	0.8	6.7	**0.001**

Appendix 5. Analysis of variance results for block and treatment effects on heights of competing woody species for three measurement periods at the Mortimer trial site. Significant p-values are in bold.

Species	Initial July 1992 Block	Initial July 1992 Treatment	Postgraze September 1992 Block	Postgraze September 1992 Treatment	Final August 1994 Block	Final August 1994 Treatment
Balsam fir						
F-ratio	0.85	0.14	2.26	1.98	0.2	4.9
P-value	0.56	0.7	0.26	0.25	0.9	0.09
Black spruce						
F-ratio	2.76	1.01	7.59	10.98	0.75	8.71
P-value	0.17	0.4	0.06	**0.045**	0.6	**0.04**
Blueberry						
F-ratio	0.81	1.51	1.45	0.001	5.99	4.28
P-value	0.6	0.3	0.44	0.98	0.14	0.17
Mountain-ash						
F-ratio	1.36	0.29	9276	841	65.2	69.2
P-value	0.46	0.6	**0.008**	**0.02**	**0.01**	**0.01**
Pin cherry						
F-ratio	9.53	1.22	9.97	16.29	3.69	7.12
P-value	**0.02**	0.3	**0.04**	**0.03**	0.16	0.08
Raspberry						
F-ratio	10.78	0.22	16.9	16.2	0.43	6.26
P-value	**0.02**	0.67	**0.02**	**0.02**	0.8	0.07
Serviceberry						
F-ratio	3.19	4.98	881.8	23.8	5.95	0.03
P-value	0.25	0.15	**0.02**	0.13	0.3	0.9
Trembling aspen						
F-ratio	8.25	0.71	125.1	2.43	1.43	0.85
P-value	**0.03**	0.5	**0.001**	0.2	0.37	0.4
White Birch						
F-ratio	5.14	0.7	6.44	6.37	0.26	1.75
P-value	0.07	0.5	0.08	0.08	0.9	0.26
Willow						
F-ratio	8.02	1.4	25.87	0.93	4.04	18.74
P-value	**0.03**	0.3	**0.01**	0.4	0.1	**0.01**

Appendix 6. Analysis of variance results for percent cover of seven vegetation classes for three measurement periods at the Mortimer trial site. Significant p-values are in bold.

Vegetation Class	Initial July 1992		Postgraze September 1992		Final August 1992	
	Block	Treatment	Block	Treatment	Block	Treatment
Trees						
F-ratio	1.25	0.01	2.2	0.37	6.34	0.93
P-value	0.4	0.9	0.3	0.6	0.051	0.4
Shrubs						
F-ratio	6.74	0.92	0.22	1.38	1.1	1.49
P-value	**0.046**	0.4	0.9	0.3	0.4	0.3
Broadleaf herbs						
F-ratio	8.84	0.78	4.27	1.63	1.71	0.2
P-value	**0.03**	0.4	0.13	0.29	0.3	0.68
Graminoids						
F-ratio	14.6	2	1.17	0.43	1.39	0.29
P-value	**0.01**	0.23	0.5	0.56	0.4	0.6
Woody						
F-ratio	5.6	0.75	0.2	1.61	1.19	1.06
P-value	0.06	0.4	0.9	0.3	0.4	0.4
Herbaceous						
F-ratio	12.37	2.22	1.13	0.74	2.25	5.43
P-value	**0.016**	0.2	0.5	0.46	0.2	0.08
Total cover						
F-ratio	8.77	1.59	0.44	1.25	0.95	1.25
P-value	**0.03**	0.3	0.77	0.34	0.5	0.3

Appendix 7. T-test results for percent cover changes of seven vegetation classes in control and grazed plots between initial and final surveys at the Mortimer trial site. Significant p-values are in bold.

Vegetation class	control		grazed	
	T-statistic	P-value	T-statistic	P-value
Trees	1.35	0.2	0.28	0.8
Shrubs	0.04	0.97	0.9	0.4
Broadleaf herbs	9.62	**0.001**	2.88	**0.045**
Graminoids	1.06	0.35	0.69	0.5
Woody	0.13	0.9	0.79	0.47
Herbaceous	19.12	**<0.001**	0.77	0.5
Total cover	2.08	0.1	1.07	0.3

Appendix 8. Analysis of variance results for block and treatment effects on height growth of competing woody species at the Silk trial site. Significant p-values are in bold.

Species	Initial July 1992		Postgraze September 1992		Final August 1994	
	Block	Treatment	Block	Treatment	Block	Treatment
Alder						
F-ratio	n.a.	n.a.	0.58	3.22	2.81	4.29
P-value	n.a.	n.a.	0.7	0.3	0.17	0.1
Beaked Hazel						
F-ratio	0.6	0.98	0.33	0.03	n.a.	n.a.
P-value	0.6	0.4	0.8	0.9	n.a.	n.a.
Mountain Maple						
F-ratio	1.78	1.38	1.48	0.87	13.45	14.91
P-value	0.3	0.3	0.4	0.4	**0.03**	**0.03**
Pin cherry						
F-ratio	0.16	5.66	1.7	10.6	0.3	2.35
P-value	0.95	0.08	0.35	**0.047**	0.8	0.2
Raspberry						
F-ratio	2.78	0.2	0.32	1.81	2.13	2.09
P-value	0.17	0.7	0.85	0.3	0.24	0.22
Trembling aspen						
F-ratio	9.39	1.93	4.43	2.36	6.64	0.06
P-value	**0.026**	0.24	0.12	0.22	**0.047**	0.8
White Birch						
F-ratio	0.22	1.34	0.24	0.02	0.48	5.16
P-value	0.9	0.3	0.9	0.9	0.7	0.09
Willow						
F-ratio	16.5	0.07	1.47	1.74	16.86	24.4
P-value	**0.009**	0.8	0.39	0.28	**0.009**	**0.008**

Appendix 9. Analysis of variance results for block and treatment effects on percent cover of seven vegetation classes for three measurement periods at the Silk trial site. Significant p-values are in bold.

Vegetation Class	Initial July 1992		Postgraze September 1992		Final August 1994	
	Block	Treatment	Block	Treatment	Block	Treatment
Trees						
F-ratio	16.95	0.23	3.4	4.85	7.02	1.17
P-value	**0.009**	0.7	0.13	0.09	**0.043**	0.3
Shrubs						
F-ratio	5.02	3.47	2.88	86.15	3.38	0.98
P-value	0.07	0.14	0.16	**0.0007**	0.13	0.39
Broadleaf herbs						
F-ratio	5	0.11	1.36	13.34	0.25	5.36
P-value	0.07	0.8	0.4	**0.02**	0.9	0.08
Graminoids						
F-ratio	5.42	0.03	9.12	4.08	1.95	1.83
P-value	0.07	0.9	**0.03**	0.11	0.3	0.25
Woody						
F-ratio	10.73	1.34	1.83	26.58	1.78	1.54
P-value	**0.02**	0.3	0.29	**0.007**	0.3	0.3
Herbaceous						
F-ratio	2.84	0.11	3.19	15.27	7.64	1.85
P-value	0.17	0.8	0.14	**0.02**	**0.037**	0.25
Total cover						
F-ratio	8.44	0.89	2.64	34.05	1.33	0.06
P-value	**0.03**	0.4	0.2	**0.004**	0.4	0.8

Appendix 10. T-test results for percent cover changes between initial and final surveys in control and grazed plots at the Silk trial site. Significant p-values are given in bold.

Vegetation class	control		grazed	
	T-statistic	P-value	T-statistic	P-value
Trees	1.57	0.2	1.69	0.17
Shrubs	1.46	0.2	3.46	**0.03**
Broadleaf herbs	2.01	0.1	2.31	0.08
Graminoids	3.89	**0.018**	1.69	0.17
Woody	1.54	0.2	3.08	**0.037**
Herbaceous	1.8	0.15	2.32	0.08
Total cover	1.72	0.16	2.83	**0.047**

Appendix 11. Analysis of variance results for treatment and ecosite effects on crop tree heights at the Gibson Lake Road trial site. Significant p-values are in bold. (d.f.=14)

	Treatment		Site	
Year	F-ratio	P-value	F-ratio	P-value
Spring 1995	0.03	1	8.86	**0.015**
Fall 1995	5.57	**0.015**	8.23	**0.018**
Fall 1996	4.64	**0.026**	9.38	**0.013**
Fall 1997	2.83	0.09	12.88	**0.006**
Fall 1998	0.8	0.5	12.29	**0.004**

Appendix 12. Analysis of variance results for treatment effects on heights of competing woody species by survey period at the Gibson Lake Road trial site. Significant p-values are in bold.

Species	Initial June 1995	Postgraze August 1996	Final August 1998
Blueberry			
F-ratio	14.54	2.22	0.64
P-value	**0.0004**	0.14	0.6
Bush honeysuckle			
F-ratio	1.687	0.95	0.24
P-value	0.24	0.48	0.9
Jack pine			
F-ratio	0.77	8.44	2.97
P-value	0.6	**0.004**	0.07
Pin cherry			
F-ratio	0.61	14.4	3.42
P-value	0.67	**0.0004**	0.0519
Serviceberry			
F-ratio	0.92	1.48	0.19
P-value	0.49	0.28	0.9
Sweetfern			
F-ratio	0.43	3.52	1.39
P-value	0.8	**0.048**	0.3
Trembling aspen			
F-ratio	0.74	1.03	1.2
P-value	0.59	0.44	0.37
White Birch			
F-ratio	4.36	1.29	1.347
P-value	**0.027**	0.35	0.3
Willow			
F-ratio	2.77	1.5	1
P-value	0.08	0.27	0.45

Appendix 13. Analysis of variance results for treatment effects on percent cover of seven vegetation classes for three survey periods at the Gibson Lake Road trial site. Significant p-values are in bold.

Vegetation class	Initial June 1995		Postgraze August 1996		Final August 1998	
	F-ratio	P-value	F-ratio	P-value	F-ratio	P-value
Trees	0.035	0.8	0.16	0.95	0.2	0.9
Shrubs	0.35	0.8	**12.89**	**0.006**	**7.95**	**0.004**
Broadleaf herbs	0.11	0.98	0.9	0.5	0.81	0.5
Graminoids	0.23	0.9	**5.3**	**0.015**	1.42	0.3
Woody	0.29	0.9	**5.86**	**0.011**	2.35	0.12
Herbaceous	0.16	0.95	1.2	0.37	1.86	0.2
Total	0.18	0.9	**5.98**	**0.01**	1.86	0.2

Appendix 14. T-test results for percent cover changes of seven vegetation classes between initial and final surveys by treatment type at the Gibson Lake Road trial site. Significant p-values are in bold.

Vegetation class	June graze		July graze		June and July graze		Spray		Control	
	T-statistic	P-value	T-statistic	P-value	T-statistic	P-value	T-statistic	P-value	T-statistic	P-value
Trees	0.29	0.8	0.95	0.4	0.9	0.4	0.14	0.9	1.08	0.3
Shrubs	3.32	**0.03**	0.23	0.8	4.61	**0.01**	0.67	0.5	2.5	0.06
Broadleaf herbs	1.7	0.16	0.99	0.4	4.62	**0.01**	3.72	**0.02**	8.37	**0.001**
Graminoids	1.07	0.3	0.005	1	0.73	0.5	0.74	0.5	1.14	0.3
Woody	1.05	0.1	0.28	0.8	2.83	**0.047**	0.7	0.5	2.13	0.1
Herbaceous	2.49	0.07	1.34	0.25	3.04	**0.04**	2.98	**0.04**	6.7	**0.003**
Total cover	2.2	0.09	0.77	.05	3.29	**0.03**	0.55	0.6	3.5	**0.025**

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