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Effectiveness of sheep grazing to control competing vegetation in white spruce reforestation

by

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This study was carried out and this paper was written on Treaty 8 territory, the traditional territory of the Beaver and Dënéndeh Nations, and the homeland of the Métis Nation.

Abstract

Changes in public attitudes toward glyphosate use on public lands for vegetation control in reforestation has spurred investigations into vegetation management techniques that do not use chemical herbicides. Sheep grazing is a potential alternative to glyphosate use, but its effectiveness has not been evaluated in boreal forests. The purpose of this study is to investigate the efficacy of sheep grazing for reducing vegetation that competes with conifer seedlings in regenerating mixedwood boreal forests in northern Alberta.

This study compares the short-term outcomes of sheep grazing on vegetation control at four regenerating clear cuts that were divided into experimental units of low grazing intensity (200 sheep × days × ha^{-1}), high grazing intensity (400) and a fenced control treatment. A total of 75 Comeau competition index plots were used to assess light competition, 45 biomass sample plots were used to evaluate grazing effects on forbs, grasses, shrubs, and deciduous tree vegetation, and grazing damage to conifer seedlings was assessed with 429 stocking assessment plots.

Overall, the heavy grazing treatment proved effective, reducing light competition by 44% (p = 0.005), while the light grazing treatment at 8% reduction was statistically non-significant. Sheep showed a strong preference for forbs with 50-60% in competition and biomass reduction for both light and heavy grazing treatments ($p < 0.05$). Only the heavy grazing treatment reduced grass and deciduous vegetation by approx. 30% (p = 0.10), while shrubs were not affected. The heavy grazing treatment did cause 6% trampling damage to regenerating conifer seedlings, while the light grazing resulted in 3% damage across all plots.

We conclude that the high intensity sheep grazing is effective in reducing light competition, unless deciduous tree competition is already beyond the sheep's reach. Additional research is required to determine whether and how long the treatment effects persist through subsequent growing seasons, or whether the grazing needs to be repeated until conifers reach a "free-to-grow" threshold, where light competition is no longer a concern.

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Introduction

Forestry in the western Canadian boreal forest often uses a clear cut silvicultural system that results in total removal of the tree canopy (Alberta Environment and Sustainable Resource Development 2021). Species assemblages that colonize harvested sites after clear cuts tends to consist of rhizomatous species, as opposed to the pyrophilic species that colonize post-fire (Haeussler and Bergeron 2004, Hart and Chen 2008). The establishment of these pioneer species can be problematic for silviculturalists when competitor plants are able to outcompete and restrict the growth of desired conifer species (Cortini and Comeau 2008). As a result, competition management is an important tool for meeting silvicultural objectives (Wagner et al. 2005).

In the western Canadian boreal forest, the natural chronosequence of succession after fire disturbance typically starts with colonization by shade-intolerant *Populus* species, as well as shrubby, herbaceous, and gramineous plants (e.g. Archambault et al 1998). Subsequently, shade-tolerant species, such as white spruce (*Picea glauca* [Moensch.] Voss) establish underneath the pioneer species and gradually outcompete them (Gray and He 2009, Reyes-Hernandez and Comeau 2014). The pioneer species community can influence the rate and direction of plant community development (Bella 1971, Royo and Carson 2006, Gärtner et al. 2014). These succession patterns result in the variable mixedwood forests that dominate much of the upland western boreal forest (Bergeron et al. 2014).

Forest policy and silviculture

While natural succession processes shape natural forest structure, managed forests are shaped by policy. Canadian forests are overwhelmingly held publicly, by the Crown, and are managed in the public interest by the provinces (CCFM, nd). In Alberta, reforestation practises on public land are governed by the *Alberta Forest Management Planning Standard* and the Reforestation Standard of Alberta (RSA) under the authority of the *Forests Act* (Alberta Sustainable Resource Development 2006, Alberta Environment and Sustainable Resource Development 2021, *Forests Act* 2021). The *Forests Act* mandates that Albertan forest license holders must reforest areas that they harvest, whether through natural regeneration or active silviculture. Forest license holders are furthermore obligated to return the same types of forest to the landscape as was harvested, a practise known as strata balancing (Alberta Sustainable Resource Development 2006). That is, if a conifer stand was harvested, it must be returned to the landscape on the appropriate reforestation timeline.

The RSA further aims to measure the mean annual increment of regenerating stands in a forest management unit and to tie the measured increment to the annual allowable cut in that management unit (Stadt et al. 2014, Alberta Environment and Sustainable Resource Development 2021). The intent of these forest policies is that license holders will be incentivised to maximize annual increment so that they may maximize their annual allowable cut (Schweitzer et al. 1972, Binkley 1980). However, the existence of silvicultural policies like the RSA indicates that the allowable cut effect is not sufficient motivation to spur investment in silviculture on its own (Luckert and Haley 1995).

Required reforestation and strata balancing combine to influence the vegetation management aspects of silviculture. A 1986 review of silvicultural success in Alberta found that, of cut blocks previously assessed to be satisfactorily regenerating fifteen years earlier, 36% contained no conifer trees (McDonough 1986). McDonough identified competing vegetation, particularly deciduous trees and grasses such as *Calamagrostis canadensis*, as a major factor in these regeneration failures. This finding immediately preceded the development of the first silvicultural surveying standards in Alberta. These standards required that cut blocks receive a "Free To Grow" survey 12 to 14 years post-harvest to ensure successful regeneration (Alberta

Environment and Sustainable Resource Development 2021). “Free To Grow” is a survey paradigm that requires a defined amount of space around a conifer tree to be free of woody competition (British Columbia Ministry of Forests 1990). Creating these competition-free spaces often required intensive vegetation management (Lieffers et al. 2008).

Glyphosate for vegetation control

The implementation of Free To Grow occurred roughly fifteen years after the release of a new form of organophosphate herbicide: glyphosate (Duke and Powles 2008). At the time of its release in the 1970s, glyphosate was promoted as effective while being safer than organochloride pesticides. Glyphosate was purpoted to effectively sorb into soils (Sprankle et al. 1975, Rueppel et al. 1977, Roy et al. 1989), preventing mobility, and could be broken down by some soil bacteria (Moore et al. 1983). Furthermore, glyphosate is a broad-spectrum, systemic herbicide and kills graminaceious, deciduous, and herbaceous plant that compete with crop trees (Duke and Powles 2008). As Free To Grow standards require intensive management of the woody vegetation that competes with crop trees, forest licensees began to look for cost-effective and efficacious vegetation management methods (Mihajlovich et al. 2012). Glyphosate fits these requirements. At present, chemical vegetation control has become the dominant vegetation management tactic in the province of Alberta, and is regarded as both effective and safe by industry (CCFM, n.d., Rolando et al. 2017).

However, there is emerging evidence that glyphosate may have unintended biological effects beyond its silvicultural use in boreal ecosystems. Glyphosate is purported to adsorb to soil particles and is considered inactive (Roy et al. 1989). However, adsorption appears to be influenced by soil characteristics and can vary considerably (Sprankle et al. 1975, Rueppel et al. 1977). Glyphosate can also be mobilized post-sorption by the addition of phosphate to the soil, and may be able to leach out of soils and enter groundwater (Gros et al. 2017). Microbial breakdown of glyphosate molecules may be reduced in boreal soils due to the colder climate and shorter growing season (Helander et al. 2012). Additionally, glyphosate has also been found to persist in the tissues of forestland flora, including those consumed by people, for much longer than previously believed (Wood 2019, Botten et al. 2021). Recent studies have also raised concerns about the impact of environmental glyphosate exposure on human health (e.g. Avila-Vasquez et al. 2018, Portier 2020, Silver et al. 2021). These concerns have led to increased public criticism of herbicide practises (Helander et al. 2012, Carvalho 2020). Forest license holders are now looking for silvicultural alternatives to herbicide for vegetation management.

Grazing as alternative vegetation control

One potential alternative to herbicide is livestock grazing on silvicultural sites. Forestry interest in grazing as vegetation control has piqued intermittently since the 1960s (see Adams 1975). This has led to trials in commercial forests in the United Kingdom (Adams 1975), Norway (Hjeljørd et al. 2014), Oregon (Leininger and Sharrow 1987, Sharrow et al. 1989, Sharrow et al. 1992a, Sharrow et al. 1992b), and British Columbia (Ellen 1992, Serra et al. 2014). Drawing on this information, sheep grazing has been suggested by Lieffers et al. (1993) and Fraser et al. (2001) for use in Albertan forests, although to date it has seen limited implementation.

Several studies have demonstrated that sheep (*Ovis aries*) grazing effectively reduces competing vegetation. In conifer forests, grazed areas have a five times lower deciduous tree density than ungrazed forests (Hjeljørd et al. 2014). Sheep grazing significantly reduced competitor biomass in one long-term study on Douglas-fir plantations (Sharrow et al. 1989). Sheep grazing can also reduce light competition by trampling vegetation, even if it is not eaten (Sharrow 2006).

However, grazing livestock can also pose a hazard to trees. Hjeljørd et al. (2014) found that trees in grazed areas were significantly more likely to be damaged than trees outside the grazed area.

Sharrow et al. (1992a, 1992b) found that sheep did damage lateral branches and, in some cases, terminal leaders of conifer crop trees, but found that these were not common or detrimental to the growth of the stand. There are also concerns that sheep may reduce the increment of the tree seedlings growing in the opening. There is evidence that, under some conditions, controlling vegetative competition with grazing may provide no benefit in terms of increasing crop tree growth (McDonald and Fiddler 1993, McDonald et al. 1996).

Finally, there are operational and business concerns regarding the use of sheep to control forest vegetation. Individual trees in the boreal forest have low marginal value (Armstrong 2014). As a result, the cost effectiveness of any silvicultural treatment is critical. To spur widespread adoption of the practise, sheep grazing would need to be demonstrated sufficiently effective and economical.

Objectives

The experiment described in the following paper was developed in partnership with Weyerhaeuser Canada Ltd., operating in Grande Prairie, AB, and the Forest Resource Improvement Association of Alberta. The overall purpose of this project is to investigate the efficacy of sheep grazing for vegetation control in the boreal forest of northern Alberta. We will do this by quantifying the short-term changes in competitive plant biomass and competition levels as a result of a silvicultural grazing program. This experiment also aims to estimate the rate of crop tree damage attributable to the grazing program. The researchers hope that this information may then be used in the development of silvicultural grazing programs.

Methods

Study area

This study takes place in Saddle Hills county in northwestern Alberta, in the northern portion of Weyerhaeuser Canada Ltd.'s Grande Prairie Forest Management Area (Figure 1). The region selected is within the Lower Foothills natural subregion, and the selected study sites had characteristics of sites with mesic moisture and nutrient regimes (Beckingham et al. 1996). The region is dominated by boreal mixedwood boreal forests. The dominant natural disturbance in the region is fire; it is estimated that the mean fire return interval for this region is less than 100 years (Andison 2006).

Two areas within the study region were selected during post-harvest vegetation assessments using the following criteria: the areas contained large, nearly contiguous clear cut areas suitable for grazing; the clear cuts needed to be the same age and planted on the same schedule; and, the clear cuts appeared to require vegetation management treatments to achieve silvicultural goals. Dominant overstory tree species in the study area include trembling aspen (*Populus tremuloides*), balsam poplar (*P. balsamifera*), and white spruce (*Picea glauca*). The plant communities found on the sites included green alder (*Alnus crispa*), highbush cranberry (*Viburnum edule*), bracted honeysuckle (*Lonicera involucrata*), and red raspberry (*Rubus idaeus*) as dominant shrubs; Lindley's aster (*Aster ciliolatus*), bunchberry (*Cornus canadensis*), fireweed (*Chamerion angustifolium*), sweet-scented bedstraw (*Gallium triflorum*), and cow parsnip (*Heracleum lanatum*) as dominant herbaceous plants; and bluejoint reedgrass (*Calamagrostis canadensis*) as the dominant graminoid.

All clear cuts selected for the grazing trial had been logged in the winter of the 2018/2019 timber year. In the spring of 2019, all selected clear cuts had been planted with white spruce at a target density of 1400 stems/ha. Planted tree seedlings had been onsite for approximately one full year at the beginning of the grazing program. Herbaceous competition potential was visually assessed in the autumn of 2019 with a flyover survey, and areas requiring vegetation management were selected for inclusion into the study.

Grazing treatments

Grazing treatments began in June 2020 and ran through August 2020 (Table 1). The clear cuts were grouped into experimental units based on nearness and visual similarities in vegetation community structure. We established two 10m x 10m ungrazed control plots in each experimental group. The control plots were exclosed using 120 cm tall metal mesh livestock fencing to prevent egress by the sheep.

Each experimental group was broken into two treatment areas. One area received a lighter graze (1000 sheep covering approximately 4 ha per day), and the other treatment area received a heavier graze (1000 sheep covering approximately 2 ha per day). The sheep were obtained from three farms in the surrounding Peace region. The sheep were moved into the sites by truck, and were delivered to a central location in the block complex. The central location would also act as a night pen for the sheep. Once the sheep were delivered to that central location, they were cared for by trained shepherds and sheepdogs. The sheep were overseen and driven by two shepherds, two herding dogs, and two guard dogs. The shepherds and dogs moved the sheep into clear cuts in the morning, and through the clear cuts throughout the day.

Measurements

Measurements were taken both before and after grazing in all sites. There were three measurements taken in all sites: an initial stocking survey of regenerating white spruce saplings one full growing season after planting, a competition assessment, and samples of vegetation biomass.

Stocking surveys are used in silviculture to determine whether a designated area contains desirable trees. The stocking survey we used in this project was based on the Reforestation Survey of Alberta's Establishment survey protocol (Alberta Agriculture and Forestry 2021), and was carried out both before and after grazing treatment. This stocking survey consists of 1.78 m radius circular plots (10 m^2) established on a grid of variable size across the whole opening. Variable spacing allows estimates of stocking to be relatively precise by (Alberta Agriculture and Forestry 2021). Each plot was located using GPS co-ordinates, but the plots were not marked with stakes or flagging tape out of concern that the sheep would trample or eat them. Within the plot area, the presence and species of coniferous and deciduous trees was recorded. A plot was considered "stocked" with conifer or deciduous trees respectively when a single specimen was present in the plot area. During post-graze surveys, any damage evident on the tree seedlings was recorded and assigned a cause.

Competition was assessed at a 10% subsample of stocking plots, as well as four measurements inside each control plot. The method used was based on the competition assessment developed by Comeau et al (1993), the Comeau Competition Index (CCI). A 1.28 m circular plot (approximately 5 m^2) was established around a conifer tree, and the vegetation surrounding that tree was assessed. Vegetation was grouped into four layers: deciduous tree species, woody shrubs, grasses, and herbaceous vegetation. Percent cover of four vegetation layers was visually estimated, and modal height of each layer was measured to the nearest centimeter. The height of the central tree was also measured. This data was collected and georeferenced using Avenza software (Avenza Systems Inc. 2020). A competition index value was then generated for each vegetation functional group using the following formula:

$$CI = \frac{\sum(C_i \times H_i)}{CTH}$$

Where:

CI = Competition Index Value

C_i = Percent cover, expressed as a percentage

H_i = Layer modal height, expressed in centimeters

CTH = Crop Tree Height, expressed in centimeters (Comeau et al. 1993)

Biomass samples were also taken from all sites and all treatments. After grazing, all of the above-ground biomass in four 50cm x 50cm square sample plots was collected and weighed in the field. Biomass samples were divided into four categories: deciduous trees, woody shrubs, dicot herbs (forbs), and grasses. While we report fresh weight biomass, we also calculated a dry weight conversion factor to make comparisons to other studies possible (Table 2) for tus purpose, subsamples of the biomass was dried in a forced air oven at 110 ^{o}C for at least 24 hours, until they reached a consistent oven-dried mass. These subsamples were used to create a conversion factor using a mean-of-ratios method, allowing the estimation of the oven-dry mass for all of the fresh samples collected.

Experimental Design and Statistical Analysis

This study uses an unbalanced, complete block design with two treatment levels and four replications (Figure 1, Appendix). Two control plots were established within each replication and excluded from all treatments. The number of observations in each replication and block varied according to the list in Table 1.

Data was analyzed using the R programming environment (R Core Team 2021). Competition Index values for all post-graze treatments were compared using a mixed model implemented with the *lmer()* function of the *lmerTest package*, where the grazing treatment being the fixed effects, and sites and plots within sites specified as random effects. The dependent variable biomass was $\log_{10}$ tranformed to meet assumptions of normality statistical analysis, while Comeau competition index values met the assumptions of normality. Contrasts among the control treatment versus the light and heavy grazing treatments were carried out with the *emmeans()* and *pairs()* functions of the *emmeans* package, which implements adjustment for multiple inference with Tukey's HSD method. Finally, the rates of stocking and damage were computed as a percentage for all treatments in all study areas. Sampling error was calculated according to Appendix 5 of the Reforestation Standard of Alberta (Alberta Agriculture and Forestry 2021).

Results

The grazing period began on June 16, 2020, and ended on August 10, 2020. Over the course of this grazing period, 73.9 ha received a heavy graze treatment and 36.3 ha received a light graze treatment. The heavy graze treatment represented a grazing intensity between 352 sheep-days/ha and 444 sheep-days/ha, and the light graze treatment represented a grazing intensity between 104 sheep-days/ha and 247 sheep-days/ha (Table 1).

The quality of the grazing varied between treatments. The higher intensity grazing treatment appeared to be more even but much higher intensity along access points into the block. The lighter intensity grazing appeared to have many more patches of ungrazed area throughout the treatment, as well as less vegetation consumption in the grazed areas. All treatments exhibited areas of lower grazing along the treeline (e.g. Figure 2).

Comeau Competition Index

Seventyfive Comeau Competition Index plots were measured after grazing and used in this analysis. These plots involved an assessment of the percent cover and measurement of the modal height of each vegetation functional group in the assessment plot. Comeau Competition Indices were calculated for each of the four vegetation functional groups and all vegetation functional groups were compared using ANOVA (Figure 3). The results of the competition index analysis suggests that the preferred forage of the sheep were forbs. For this vegetation group, the competition index was reduced by about 50-60% under both the high and low grazing treatment with statistically significant effects (Figure 3, panel Forbs, ctrl-low: p=0.007, ctrl-high: p=0.008). For deciduous and grass vegetation types, only the heavy grazing treatment showed a sizeable reduction in competition of approximately 30% (Figure 3, panel Grass, ctrl-high: p=0.085, and panel Decid Trees, ctrl-high: p=0.108). There is no notable difference among the treatments for reduction in shrub coverage (Figure 3, panel Shrubs, n.s. at α=0.05). Across all vegetation types, the heavy grazing treatment reduced light competition by 44% (p = 0.005), while the light grazing treatment at 8% reduction was statistically non-significant at α=0.05.

Comeau Competition Index considers two vegetation characteristics: percent cover and modal height. A decline in Comeau Competition Index after grazing occurs as a result of a decline in at least one of those characteristics. This is particularly relevant to the results of our Deciduous Comeau Competition Index comparison. The sheep in this experiment did not tend to eat woody plant material. At lower grazing intensities, sheep ate leaves that they could easily reach, which decreased leaf cover somewhat but had a negligible impact on height (Figure 4a). At higher grazing intensities, the sheep would press down smaller trees and strip them of leaves, but the trees retained some ability to rebound (Figure 4b). This resulted in a smaller treatment effect for deciduous trees compared to forb vegetation.

Furthermore, with respect to Comeau Competition Index, the grass vegetation functional group was affected differently by grazing than the forb vegetation group, even though both groups represent herbaceous vegetation. In this trial, there were many areas that saw considerable grass trampling by the sheep without commensurate grass consumption. The Comeau Competition Index measurements did not capture this as a full reduction in competition because the tramped vegetation matter remained onsite and still contributed to percent cover. In contrast, plants in the forb vegetation functional group were predominantly consumed rather than trampled.

Biomass Measurements

The grazing treatments removed approximately two thirds of the total biomass from the treatment areas, when compared to control (Figure 5). Note that the y-axis of Figure 5 is $\log_{10}$ transformed to meet assumptions of normality for statistical tests. All grazing vs. control treatments were statistically significant at α=0.05, except Control versus High grazing treatments for deciduous trees, and Control versus Low grazing treatments for grasses. The biomass reductions appear consistent with expectations, except for deciduous trees. This anomaly can be traced to the presence of large deciduous trees in the high grazing treatment at a single site (Site A), whereas all other sites showed a consistent decline.

While sheep will eat the leaves of deciduous trees, they did not eat the woody stems of the plants (Figure 4). Once deciduous trees exceed a certain size (as in the case of the high-grazing treatment plot of Site A), sheep grazing becomes ineffective as they can no longer reach the crown of competing deciduous trees. Forb vegetation was the most thoroughly consumed of all the vegetation functional groups, and showed the largest decreases in remaining biomass with increasing grazing intensity (Figure 5). Shrubs and grasses had similar patterns of reduction in biomass to forbs as grazing intensity increased, but were lower contributors to total plot biomass than either forbs or deciduous trees.

Stocking and Grazing-Related Damage

For the purposes of the stocking surveys required by the province of Alberta, the minimum acceptable conifer stocking percentage for cut blocks regenerating to a conifer landbase is 70% (Alberta Agriculture and Forestry 2021). Two of our treatment areas did not satisfy this stocking requirement by a small margin (Table 3), but the overall stocking percentage of the experiment was 75% for the low grazing and 77% for the high grazing areas, satisfying provincial reforestation requirements.

With respect to grazing-related tree damage, areas subjected to low-intensity grazing averaged 3% and high intensity grazing caused 6% damage, relative to stocked plots (Table 3). Relative to all plots, stocking rates decreased by 2 and 4 percentage points on average for the low and high grazing intensity, respectively. That means that overall stocking rate requirements for the experiment were still satisfied after grazing with 73% for both the low and high grazing treatments. The most common types of grazing-related damage included trampling damage and broken terminal leaders. There was no evidence found of sheep eating the crop trees; all noted damage pertained to the sheep walking over or bedding down on conifer seedlings.

Discussion

These results have demonstrated the effectiveness of sheep grazing as a silvicultural brush control treatment in the short-term. The higher intensity grazing treatment resulted in approximately a 50% reduction in Comeau Competition Index values and approximately a 50% reduction in total vegetation biomass, while the lighter intensity grazing treatment resulted in approximately a 10% reduction in Comeau Competition Index values and approximately a 50% reduction in total vegetation biomass, relative to control. While both Comeau Competition Index and vegetation biomass measurements were used to estimate the amount of vegetation that was removed by the grazing treatments, it is important to remember that these two measurements are estimating different things: while vegetation biomass estimates the mass of vegetation consumed by the sheep, the Comeau Competition Index aims to estimate the amount of light competition experienced by a particular tree. In this respect, the Comeau Competition Index measurements may be more important to a forest manager than the biomass measurements. With that in mind, I conclude that the higher intensity grazing treatment was most effective at reducing vegetative competition in these four treatment areas.

However, these results are somewhat disappointing. The most problematic competitors for conifer seedlings are deciduous trees and grasses (Lieffers et al. 1993, Lieffers and Stadt 1994, Filipescu and Comeau 2007, Cortini et al. 2017). The grazing treatments used in this study greatly reduced competition caused by forbs and did not significantly reduce competition caused by either deciduous trees or by grass (Figure 3). This result may be partially explained by the availability of forbs on the treatment sites; Leininger and Sharrow (1987) found that sheep grazing Douglas-fir plantations consumed more grass in sites where grass was the predominant herbaceous vegetation. These sites had higher forb mass than grass mass in control plots, and, commensurately, saw more forb consumption than grass consumption by mass.

While this result is discouraging, this study did not fully capture the reduction in grass competition due to trampling. One cause of mortality from grass competition is snow press: during the winter, snow presses down on the grass, which can also press down tree seedlings, resulting in poor tree form and mortality (Wang and Kemball 2005). This can remain a risk even following herbicide application because herbicide leaves the now-dead grass standing onsite. Trees are at risk for snow press damage until they are large enough to withstand the weight of grass and snow. Grass that was trampled by sheep may not facilitate snow press in the same way, because the grass is trampled well before the first snowfall of the year, and the motion of the flock moving through the trampled grass prevents tree seedlings from becoming trapped beneath it. This means that even though the grass was not removed, there may still be a benefit to the trees (see Sharrow 2006).

Tree damage rates present an important caveat when discussing the effectiveness of a grazing program. The tree damage rates in this program ranged to as high as 17.5% of trees surveyed for the more effective, high intensity grazing treatment (Table 3). This has important implications for potential repeated treatments. Newsome et al (1995) suggested using periodic re-grazing for up to 5 seasons. There may also be growth gains that are possible with repeated treatments (Serra et al. 2014). However, the damage rates seen in the high intensity grazing treatment in this study contraindicate using a high-intensity grazing treatment multiple times in the same cut block, as this may have a detrimental effect on satisfactory crop tree stocking.

Planning aspects: timing and community composition

The application of a grazing program requires considerable planning. Ellen (2003) suggested that silvicultural grazing operations require sufficiently large "runs" of grazing land in order to be practicable. The results from this study emphasize a further domain in which operational planning is important: grazing timing.

As evidenced in this study, sheep can be selective of what they eat; in this study, the sheep expressed a strong preference for forbs and a lesser one for shrubs (Figure 5). Sheep are willing to eat past satiety if the available food is palatable enough (Baumont et al. 2009). Sheep select preferred forage based on plant characteristics that can vary seasonally, such amino acid content, fat content, and mineral content, may also change through the growing season and alter the forage suitability of the plant (Tew 1970, Gloser 2002). Other plants may be entirely avoided due to secondary compound presence or cyanogenic properties (Cooper-Driver et al. 1977). It is therefore important to understand the composition of the plant community on a site and how the characteristics of those plants change through time before developing a grazing prescription.

Grazing timing is also important when planning a grazing program. This is for two reasons: first, the palatability of some plants may change through the growing season, and second, the ability of plants to compensate for biomass lost by flushing new growth after the grazing period. Compensatory growth is a documented response to mechanical damage during the growing season, particularly in some boreal species (e.g. Hogg and Lieffers 1991, Carson et al. 2009). It is also a biological process that is relevant to mechanical vegetation control programs, and not to glyphosate-based vegetation control programs, because glyphosate kills the whole plant by interfering with shikimic acid metabolic pathway (Duke and Powells 2008). Carson et al. (2009) found that removing terminal buds from aspen saplings resulted in higher bud density the following year, resulting in more higher leaf area the next year. With respect to competitive grass species, Hogg and Lieffers (1991) found that *Calamagrostis canadensis* plants that were cut later in the growing season did not regrow as much aboveground biomass as plants that were cut earlier in the season. That suggests that, later in the season, *Calamagrostis canadensis* allocates more resources towards its roots; so, while later season grazing could look more effective, the plant may be able to survive and return during the subsequent growing season. Also important is the number of times per growing season a plant is mechanically damaged; Corns and Schraa (1962) found that *Calamagrostis canadensis* plants that were cut multiple times per growing season produced less than plants that were cut just once per season. Both aspen and *Calamagrostis canadensis* exhibit higher capacity for compensatory growth when there is greater nutrient availability (Corns and Schraa 1962, Erbilgin et al. 2014). Site characteristics, seasonality, and repeated treatments will therefore intersect and influence the success of any grazing program. More research is needed to identify the role of compensatory growth in a grazing program and to determine whether repeated treatments are optimal for vegetation control. There is also a need for research into the persistence of the treatment effects beyond the treatment year.

Potential for application

The results of this study suggest that grazing can control vegetative competition in regenerating cut blocks. A further problem is how grazing can fit into modern silviculture planning. Modern silviculture plans must include not only silvicultural goals but also the needs of other land users and the preservation of the environment, all while appropriately managing costs.

One caveat specific to livestock grazing on public lands is the potential for disease transmission between the sheep and other animals, whether wild or domestic. Domestic sheep carry diseases that can affect both bison and wild sheep, both of which are present in parts of Alberta. Bison (*Bison bison*) can contract malignant catarrhal fever from domesticated sheep without being within a kilometer of them (Li et al. 2008). Malignant catarrhal fever is a disease caused by a herpes virus that is carried by sheep is often rapidly fatal in bison (Berezowski et al. 2005). Wild sheep, such as Bighorn Sheep (*Ovis canadensis*), can contract pasteurellosis pneumonia from contact with domestic sheep (Foreyt and Jessup 1982, Onkerda et al. 1998, Miller et al. 2008). Both of these diseases present management concerns for wild populations as well as livestock (Carpenter et al. 2014). Any plan involving sheep grazing near the range of these species should account for the risk of disease transmission.

Another risk presented by grazing is soil compaction and damage to stream banks caused by sheep and shepherds (Fraser et al. 2001). While there is some evidence that repeated sheep grazing does result in higher soil bulk density and decreased pore size, these effects appear to be reversible with time (Sharrow 2007). Glimp and Swanson (1994) identified streambank trampling as an important and controllable influence that grazing livestock exert on stream channels and watersheds, and they suggest that this be minimized. The current logging ground rules in Alberta require treed buffers around streams (see Alberta Environment and Sustainable Resource Development 2006), which may mitigate erosional effects caused by grazing itself (Zaimes et al. 2004).

For the past 15 years, glyphosate has been the vegetation control method of choice for many of Alberta's forest licensees (Mihajlovich et al. 2012). As a broad-spectrum herbicide, glyphosate can effectively control both grassy and deciduous competition (Lund-Høie and Rognstad 1990). However, the criticism of glyphosate use encourages the exploration of alternatives, whether those are other herbicides or physical controls, such as manual brushing and grazing. Compared to other forms of physical vegetation control, sheep grazing poses low risks to operators and crop trees, while performing moderately well under challenging site conditions (Newsome et al. 1995). The marginal cost of these treatments is also very important, because the marginal value of any one tree in an Albertan forest is low (see Armstrong 2014). Foresters may want to consider a combined program of herbicide and grazing in order to maximize the control of problematic vegetation while controlling management costs.

In summary, sheep grazing does effectively reduce both the amount of light competition experienced by the tree seedings, and the amount of vegetation biomass present on site after grazing. However, these findings do not demonstrate that grazing significantly reduces crop tree competition caused by grass or deciduous trees. Grazing intensity appeared to be important; higher intensity grazing significantly reduced both competition index values and onsite vegetation biomass. However, higher grazing intensity was associated with more damage to crop trees, so higher intensity treatment may have trade offs with tree morbidity and mortality.

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Tables

Table 1. Experimental design statistics, start dates of grazing in the year 2000, subsequent dates of assessement of stocking and competition plots, and dates of sampling of biomass plots (4 plots for each treatment). Grazing intensity is given in units of sheep × days × ha^{-1}, with 1000 sheep used to graze sites A-C and 500 sheep for site D.

Block and location	Area (ha)	Grazing treatment	Grazing intensity	Number of plots		Start dates of		
				Stocking	CCI	Grazing	Assessment	Sampling
Site A	20.18	Low	248	67	7	16-Jun	7-Jul	4-Jul
55.6470°N	12.26	High	408	57	6	29-Jun	7-Jul	4-Jul
119.4675°W	0.02	Control	0	0	8	-	7-Jul	6-Jul
Site B	9.56	Low	105	67	10	28-Jun	7-Jul	8-Jul
55.6394°N	22.68	High	353	25	2	21-Jun	7-Jul	8-Jul
119.4688W°	0.02	Control	0	0	8	-	7-Jul	8-Jul
Site C	5.35	Low	187	15	2	20-Jul	5-Aug	5-Aug
55.6269°N	29.27	High	444	84	8	21-Jul	5-Aug	5-Aug
119.4193°W	0.02	Control	0	0	8	-	5-Aug	5-Aug
Site D	1.18	Low	212	12	2	2-Aug	17-Aug	18-Aug
55.6204°N	9.67	High	362	102	10	3-Aug	17-Aug	18-Aug
119.4386°W	0.02	Control	0	0	4	-	17-Aug	18-Aug

Table 2. Means and standard errors of dry:fresh weight ratios for converting fresh biomass to dry biomass for the samples collected in this study.

Functional group	Dry to fresh weight ratio	Standard error	Number of samples
Decid. Trees	0.635	0.034	28
Forbs	0.439	0.031	35
Grasses	0.619	0.042	17
Shrubs	0.649	0.030	33

Table 3. Stocking level as percentage of stocking plots that contained at least one regenerating conifer, and percent damage after grazing, expressed as the percentage of stocked plots that did not retain at least one undamaged conifer seedling after the grazing treatment.

	Stocking level		Damage after grazing	
Block	Low	High	Low	High
Site A	58%	79%	3%	10%
Site B	84%	84%	0%	2%
Site C	73%	82%	10%	6%
Site D	83%	66%	0%	5%
Average	75%	77%	3%	6%

Figures

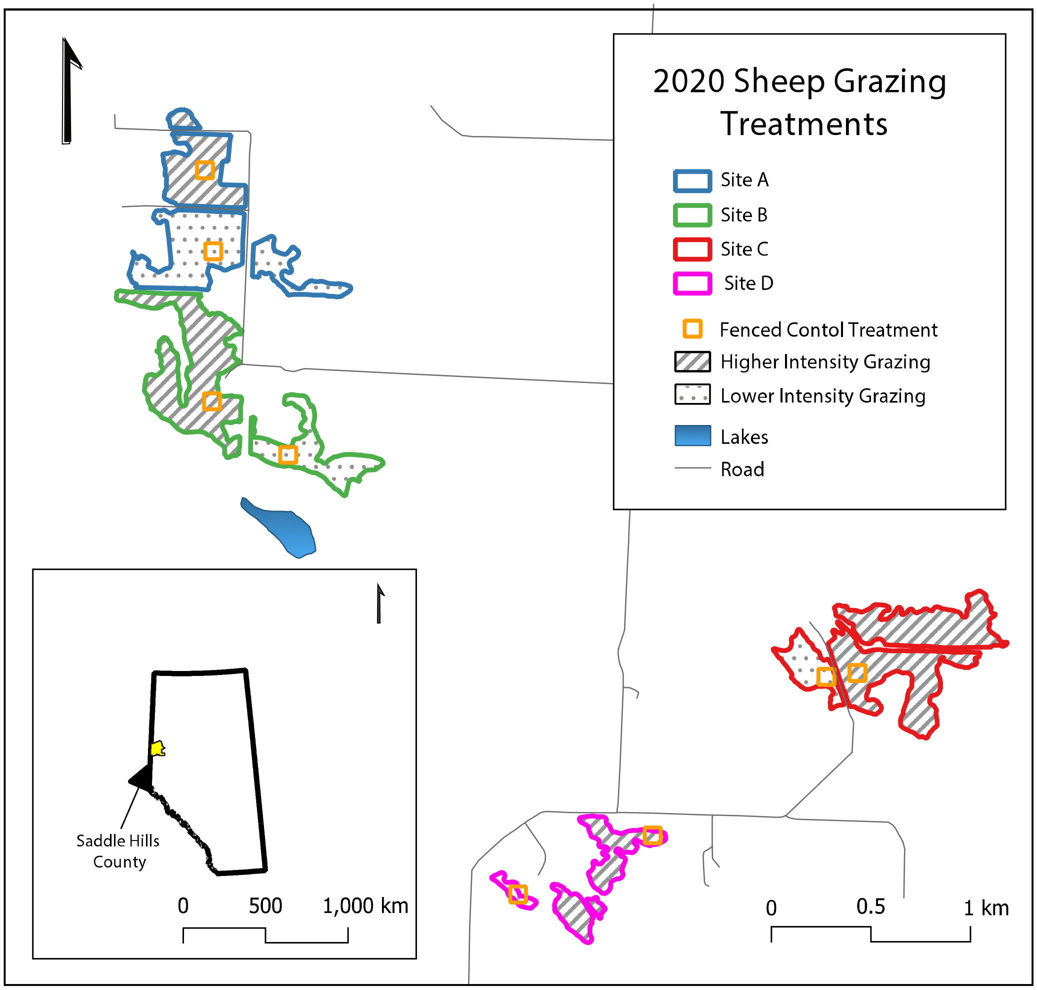


Figure 1. Overview of the arrangement of sampled clear cuts (blocks A, B, C, D) and treatments (control, low- and high-intensity grazing). The inset shows a map of Alberta and Saddle Hills County where the study site is located at approximately 55.64°N and 119.44°W. Base map features were obtained from the Government of Alberta (2021).

Figure 2. Photograph of Site B after a light grazing treatment. Some deciduous trees are partially stripped of leaves, and there is visible ungrazed area in the background.

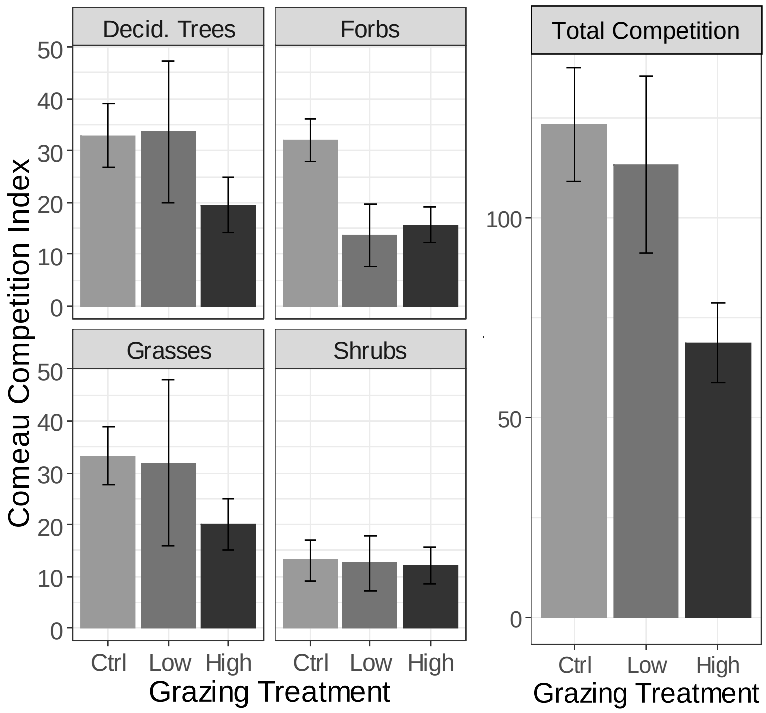


Figure 3. Comeau Competition Index results for four vegetation functional groups (left) and total competition (right). The treatments are high-intensity grazing (High), low-intensity grazing (Low), and a fenced control treatment without grazing (Ctrl). Error bars represent standard errors of the mean.

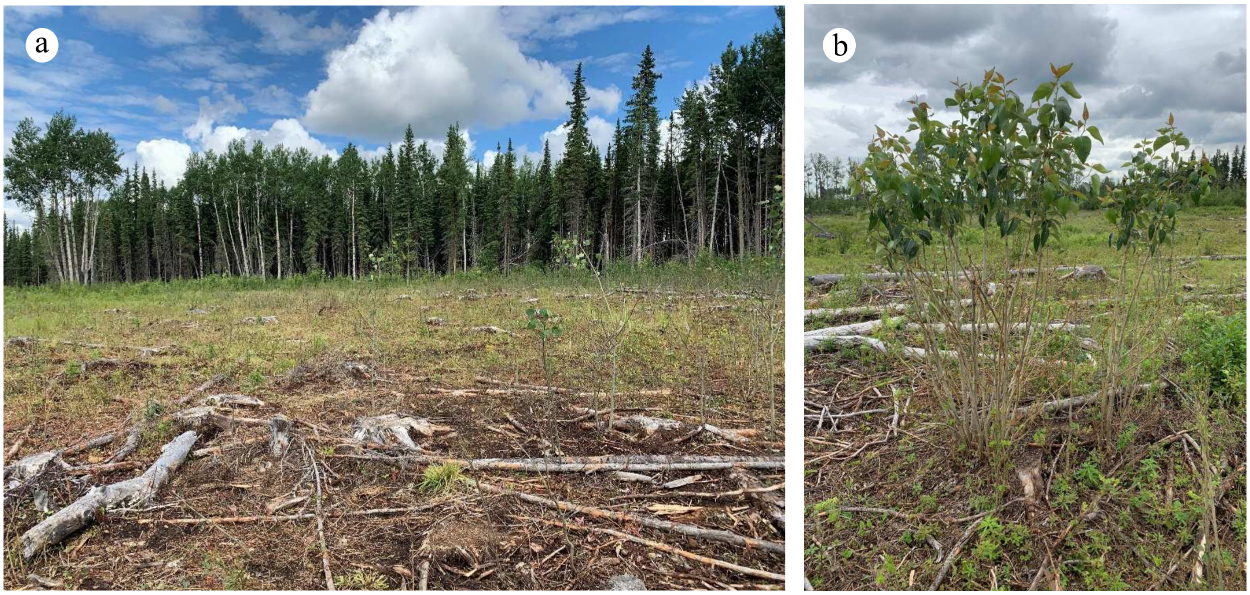


Figure 4. Site A after a high intensity grazing treatment (a), and an example of a balsam poplar clump having had its leaves stripped as high as the sheep could easily reach (b). Grazing efficacy for vegetation control appears compromised once deciduous tree competition has exceeded the reach of sheep.

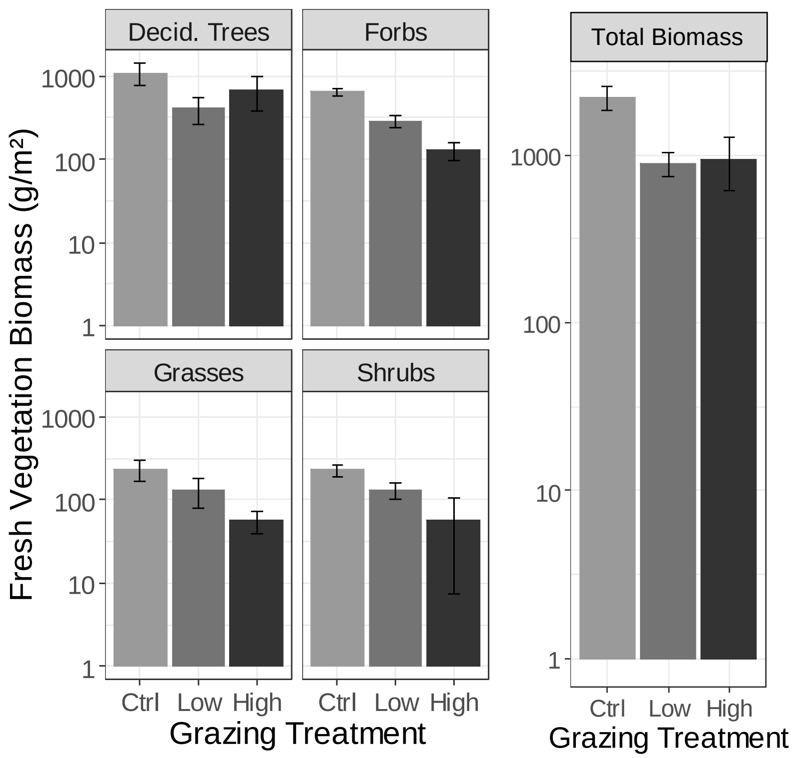
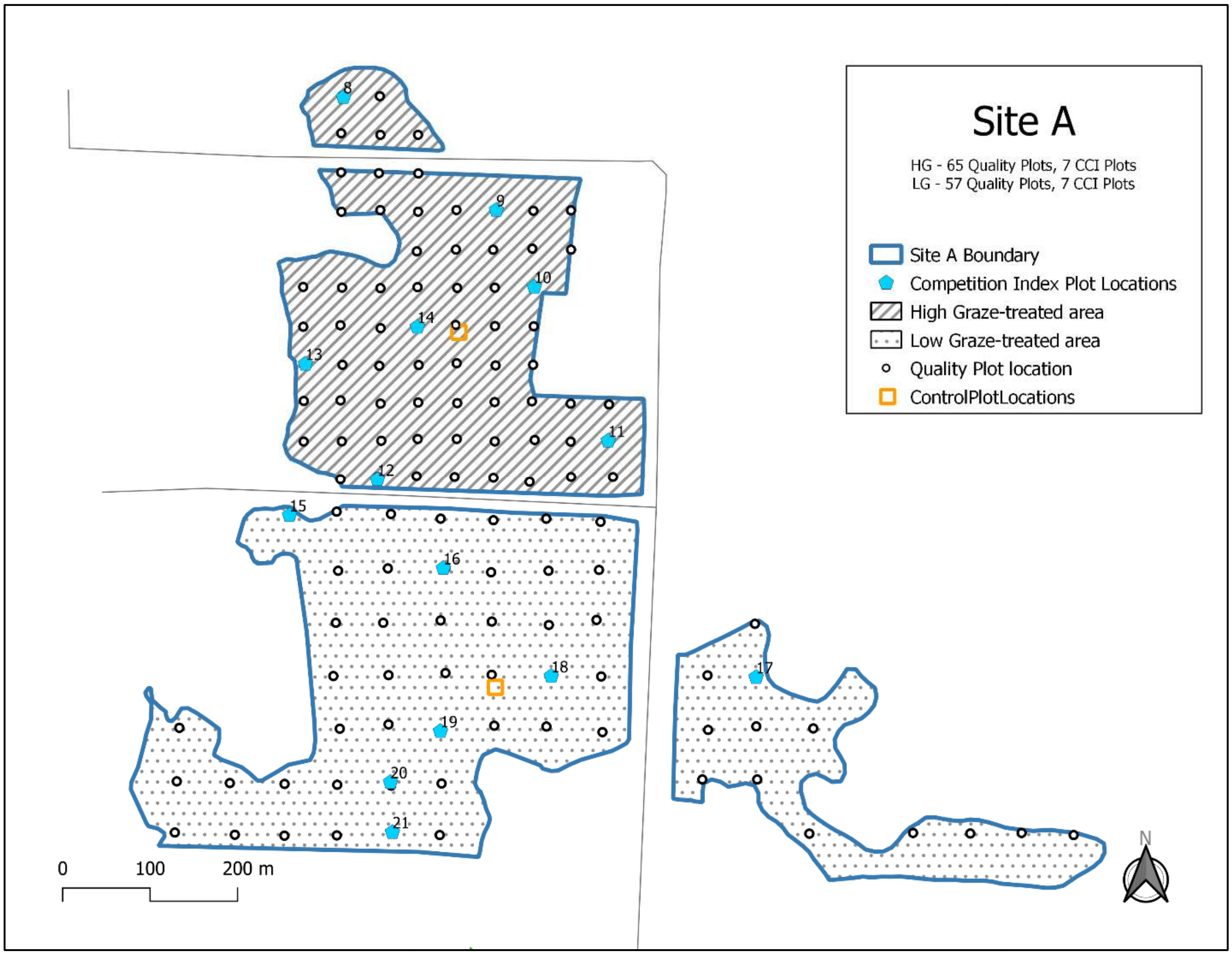
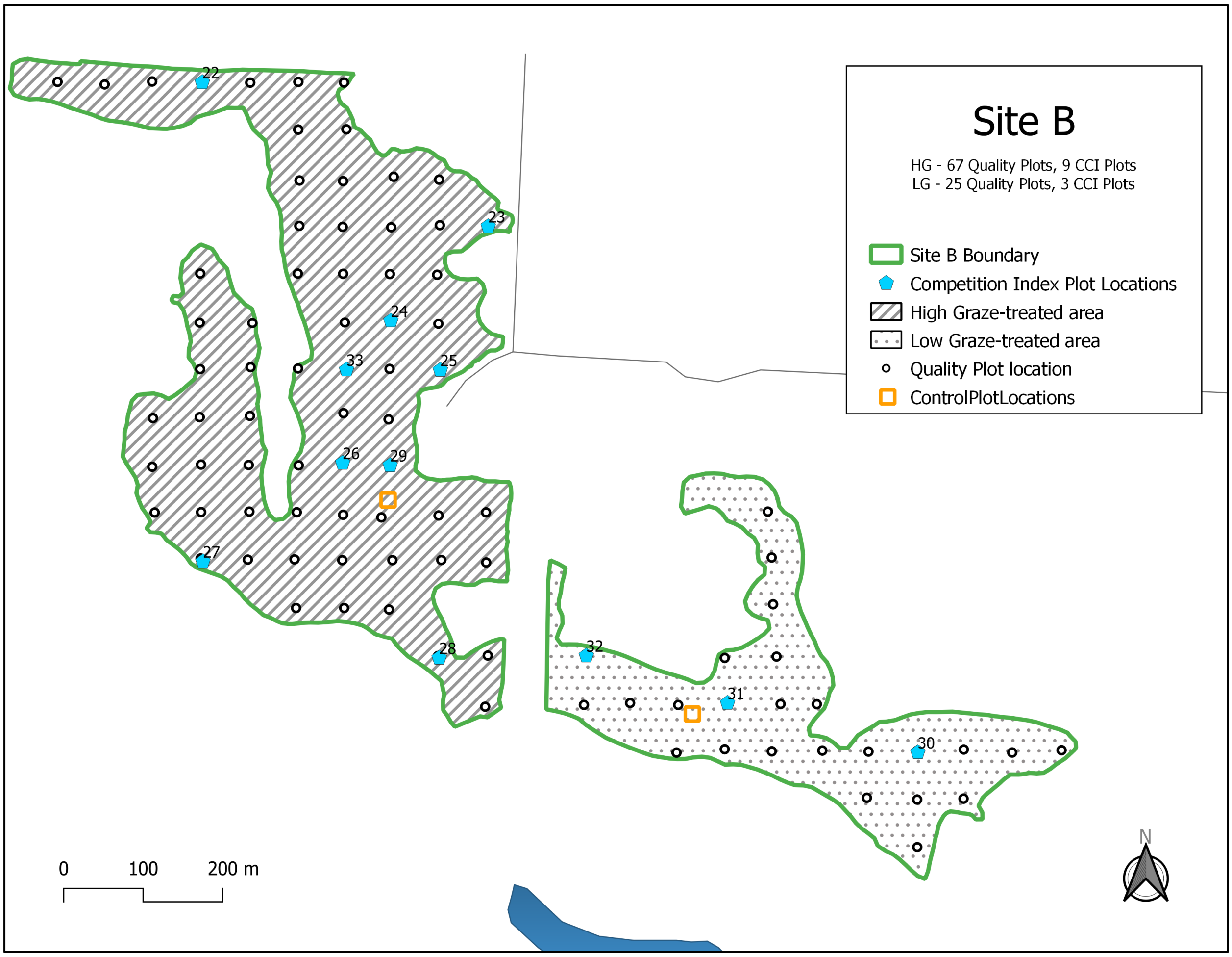


Figure 5. Fresh weights of vegetation collected in 50cm x 50cm square plots for four vegetation functional groups (left) and total biomass (right). The treatments are high-intensity grazing (High), low-intensity grazing (Low), and a fenced control treatment without grazing (Ctrl). Error bars represent standard errors of the mean. Note that the y-axis is on a $\log_{10}$ transformed.

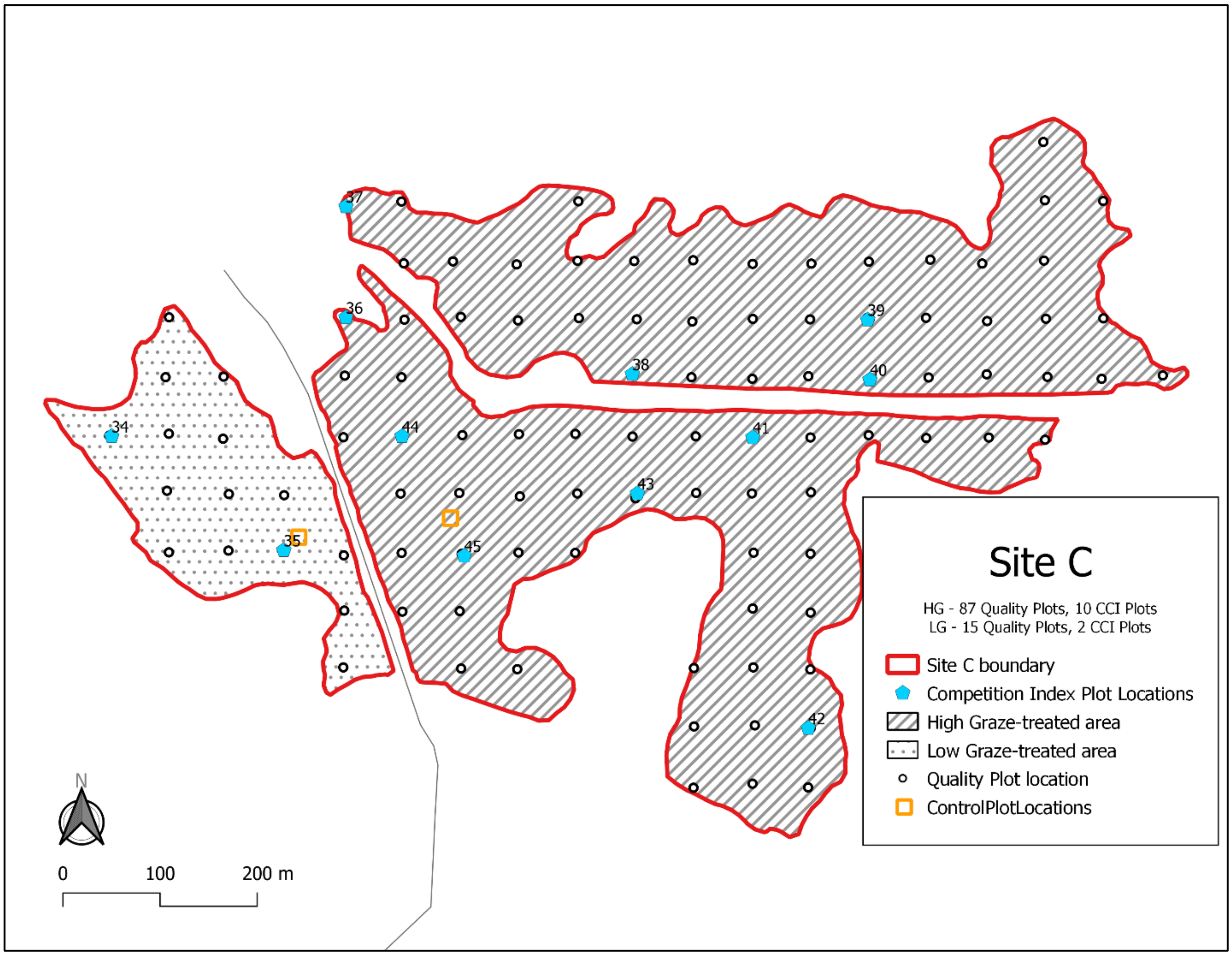
Appendix

Detailed maps of Sites A-D with treatment areas, stocking (quality) plot locations, competition index plot locations, and fenced control plots.

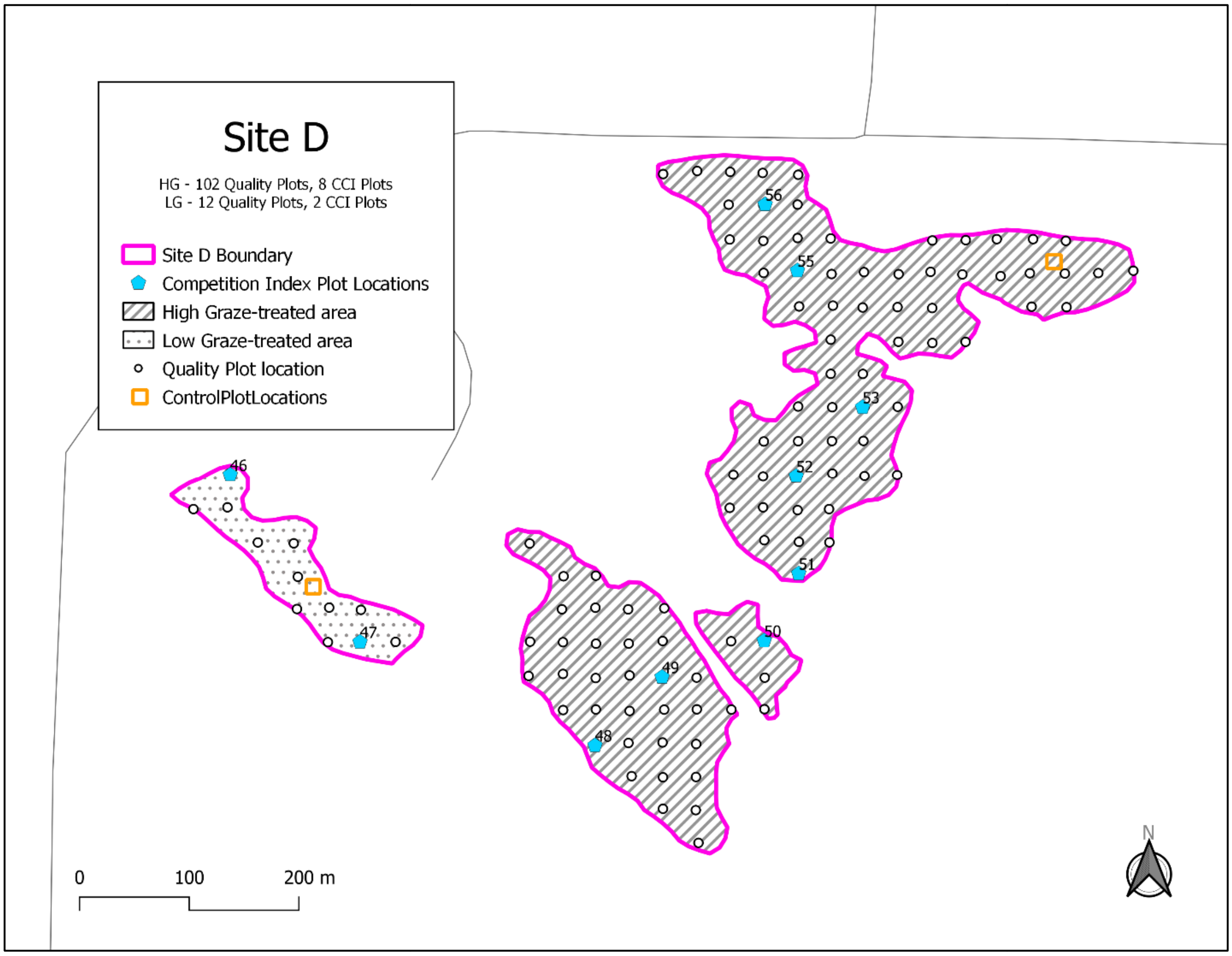




Site B
HG - 67 Quality Plots, 9 CCI Plots
LG - 25 Quality Plots, 3 CCI Plots
Site B Boundary
Competition Index Plot Locations
High Graze-treated area
Low Graze-treated area
Quality Plot location
ControlPlotLocations
22
23
24
33
25
26
29
27
28
32
31
30
0
100
200 m
N



Site C
HG - 87 Quality Plots, 10 CCI Plots
LG - 15 Quality Plots, 2 CCI Plots
Site C boundary
Competition Index Plot Locations
High Graze-treated area
Low Graze-treated area
Quality Plot location
ControlPlotLocations
N
0
100
200 m
34
35
36
37
38
39
40
41
42
43
44
45


Site D
HG - 102 Quality Plots, 8 CCI Plots
LG - 12 Quality Plots, 2 CCI Plots
Site D Boundary
Competition Index Plot Locations
High Graze-treated area
Low Graze-treated area
Quality Plot location
ControlPlotLocations
46
47
48
49
50
51
52
53
55
56
0
100
200 m
N