Vegetation Composition, Tree Growth and Ungulate Use Response to Three Forestry Site Preparations

 

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Summary

This report was prepared by Syringa Ecological Consulting, LLC. for and in collaboration with the Upper Columbia United Tribes' (UCUT) Timber, Fish, and Wildlife Program. It summarizes a multi-year study on the effects of post timber harvest vegetation suppression treatments, known as site preparations, on vegetation composition and ungulate use. Study sites were located on tribal lands of the Kalispel Tribe of Indians, the Coeur d'Alene Tribe of Indians, and the Colville Confederated Tribes.

Prior to the 1990's most site preparations in eastern Washington forests consisted of broadcast burning and mechanical clearing which involves using heavy machinery to masticate logging debris and scarify the land. Both of these site preparations techniques expose mineral soils and reduce competing vegetation prior to planting crop trees. The use of herbicide as a site preparation treatment can target specific vegetation species and has the potential to effect vegetation composition for up to ten years post application. Since the early 1990's the use of herbicide has steadily increased in eastern Washington to roughly 10,000 acres per year on both private and state lands. This increase in use of herbicide has led the UCUT to investigate the impacts to native vegetation and ungulate use.

This study compares these three different site preparations (broadcast burning, mechanical, and herbicide) along with no vegetation suppression on five tribal harvest units. We investigated the multi-year effect on vegetation structure including forms important to ungulate browse, tree height and survival, and ungulate use in these treatments.

This study could not have been conducted without the help of tribal wildlife and forestry managers, the staff at UCUT, as well as volunteers that helped to erect fencing.

Cover photos showing vegetation cover at year 3 on a study sites with no vegetation suppression (left) and treated with herbicide (right).

Introduction

The Upper Columbia United Tribes (UCUT) and it's five member Tribes, The Spokane Tribe, the Kalispel Tribe of Indians, the Colville Confederated Tribes, the Kootenai Tribe of Idaho and the Coeur d' Alene Tribe have forestry activities on reservation lands as well as in their traditional territories. The UCUT and many other Native American Tribes manage timber lands in a holistic manner, balancing the economic value of timber harvest with the conservation of habitat for important game species, and maintaining culturally important native vegetation. This can contrast with many current industrial forest management practices that prioritize obtaining the maximum yield with shorter rotations. Tribal land managers of the Upper Columbia United Tribes are concerned that intensive forest management practices can have negative impacts on native vegetation and important ungulate species.

Ungulates utilize disturbed forest patches for the nutritional early seral vegetation specifically native forbs and deciduous shrubs (Jenkins and Starkey, 1996; Smith et al., 2020; Ulappa et al., 2020). These early successional forests have vegetation structure with high richness and abundance compared to closed canopy forests (Hagar, 2007). The early seral vegetation is highly competitive, is often highly palatable and invests energy into growth instead of chemical or mechanical defenses (Witmer et al., 1985; Augustine & McNaughten, 1988). Thus, these early successional forests are essential forage habitat for ungulates.

Historic disturbance regimes of wildfires and windstorms were the main drivers in creating early successional forest patches (Agee, 1993), but due to fire suppression and modern harvest practices, the majority of early successional forest openings have been created through timber harvest. With the reduction of harvest on public lands over that last several decades the majority of early successional stands are on private timber property (Washington Department of Natural Resources, 2012; Oswalt et al., 2014). To meet the increased demands on a smaller land base industrial timber companies commonly utilize intensive forestry practices to increase yields. In the Pacific Northwest these methods include the use of genetically improved saplings, chemical site prep, stocking control and shorter rotation (Wagner et al., 2004; Vance et al. 2010; Demarais et al. 2017). Industrial timber mangers aim to reduce harvest rotations from 60 to 40 years.

Many tribal members utilize their reservation's forest lands for economic value as well as subsistence hunting and gathering plants for food and cultural purposes. This cultural and economic reliance on these forests has led many tribes to view the use of herbicides differently than industrial land managers. As an example, the Colville Confederated Tribes, managing some of the largest tribal owned timber land in Washington, does not use broad scale application of herbicides according to their timber management plan (Marc Gauthier, UCUT 2020).

Although the research suggests that selective herbicides poses no toxicological health risks for humans or the environment, concerns still persist (Buse et al., 1995; Wagner et al., 1998). A survey of First Nations Tribes in Ontario, Canada state concerns over health risks as well as the use of herbicides as being incongruent with their cultural worldview (Kayahara & Armstrong, 2015). Herbicide residue remaining on plants has prompted research in Northern California where Ando et al. (2003) detected forest herbicides on several culturally important plant parts up to 80 weeks post application and detected herbicide residue in plants off of the application site, noting that the herbicide Hexazinone has a high potential to move off-site.

Along with cultural interests, there is increasing research that points to industrial forest practices having a negative effect on ecological processes, including ungulate habitat (Freedman et al., 1993; Geary et al., 2017; Ulappa et al., 2020). These management techniques do not always account for the importance of early seral forests for biodiversity of native plants and forage for ungulate species as well as other key ecological services (Swanson et al., 2011; Pekin et al., 2014).

Post timber harvest site preparations aim to suppress competing vegetation and therefore create suitable habitat for increased crop tree growth and survival. These preparations can include broadcast burn, mechanical scraping and mastication, and chemical treatments with targeted herbicides. While the role of herbicide application in site preparation is to suppress vegetation (ideally for multiple years); broadcast burns and mechanical also reduce harvest debris and expose mineral soils.

The use of forest herbicides can alter the successional pathway of forests for up to a decade reducing the early seral vegetation and compressing successional stages (Dyrness, 1973; Halpen & Spies, 1995; Lautenschlager & Sullivan, 2003; Demarais et al., 2017; Ulappa, 2020). Herbicide site preparations can have a variable effect on the availability and nutritional quality of individual forage species, sometimes making species less palatable and/or contain less nutritional value (Strong & Gates, 2005; Edenius et al., 2013, Geary et al., 2017; Ulappa et al., 2020; Raymond and Servello, 1997).

Management of forests and ungulates are often disconnected and there is a need for adaptive, regional management strategies (Wisdom et al., 2006; Beguin et al., 2016). The reduction of time and area of early successional forests reduces critical ecological functions including ungulate forage habitat (Swanson et al. 2010). Recent research has found that maintaining plant diversity during the first few years of stand establishment can help reduce the negative effect of ungulate browse on valuable tree species (Beguin et al., 2016; Stokey et al., 2018; 2020).

Most studies on the ecosystem effects of herbicide use for timber site preparation are regional, reflecting two of the biggest timber regions of the US; the southeast and the coastal range of the Pacific Northwest; and studies cite this as a gap in data for regional forest managers (Wagner et al., 2004, Lautenshlager & Sullivan, 2004). The forests of the Inland Northwest are significantly different climatically from these other regions with drier, shorter growing seasons and the majority of precipitation falling as snow. This reflects a different composition of understory vegetation and competition pressure.

The lands of the Upper Columbia United Tribes share inholdings and many boundaries with commercial timberlands. Wildlife managers from these tribes have reported seeing less game on areas where intensive forest management practices rely on herbicides while seeing similar tree survival and more game in areas without herbicide application (Corey Peone, Colville Confederated Tribes, 2020). This study is a step towards informing regional managers on the potential impacts of different timber site preparation techniques on early successional forest and on best practices that can support both timber harvest and ungulate populations in forests of the Inland Northwest.

Methods

Industry Site Photo Points and Observational Survey

Twelve industrial timber site photo points were selected using Washington Department of Natural Resources' Forest Practices Application Review (FPAR) application data along with the ability to document spray dates. Sites were also chosen based on access and visibility from public roads. From 2016 to 2020 photos were taken at least twice during the growing season. While at each site, general plant composition notes were gathered based on forb species cover, shrub presence, and estimated tree height.

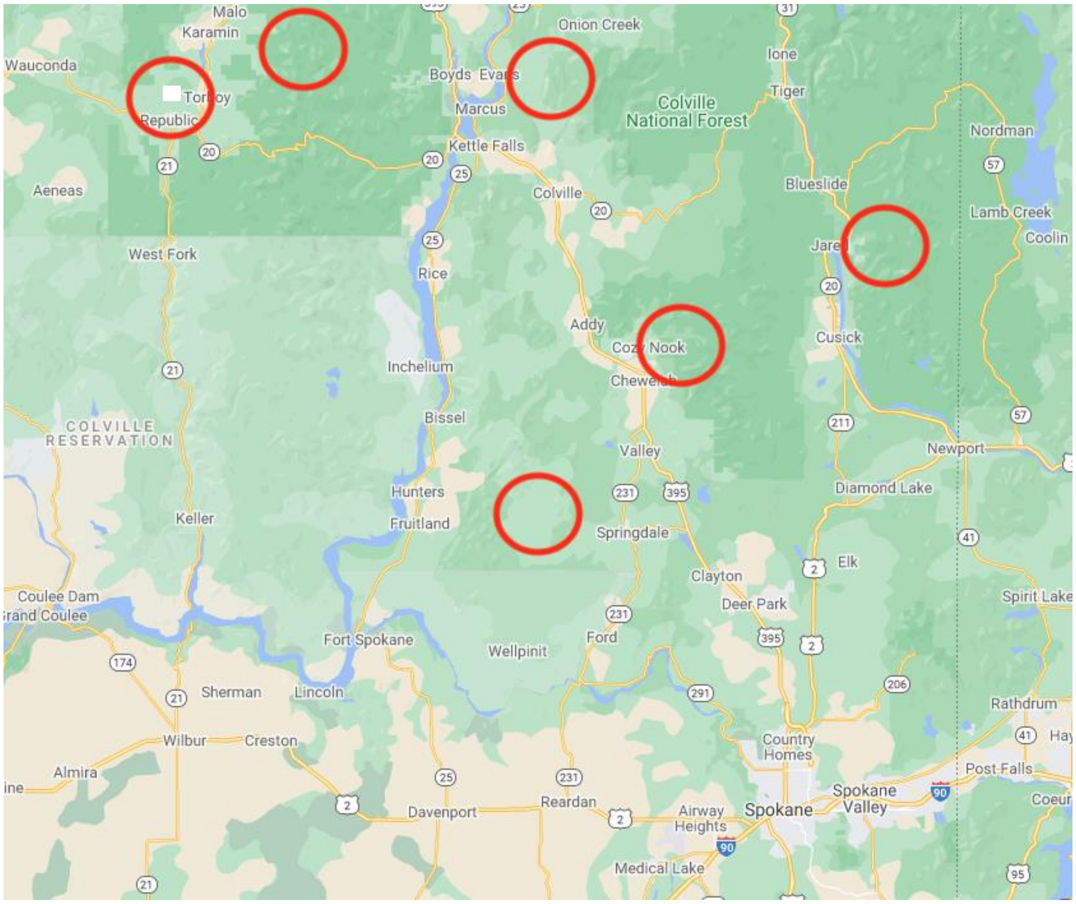

Figure 1. Map of northeastern Washington State with approximate locations of industrial timberland harvest photo site points, circled in red.

UCUT Study Site Info

Five experimental UCUT study sites were located on tribal timber lands in northeastern Washington and northern Idaho; on lands managed by the Colville Confederated Tribes, the Kalispel Tribe of Indians, and the Coeur d'Alene Tribe. Sites were selected based on tribal harvest schedules and ability to implement at least two site prep treatments and a control where no vegetation suppression occurred. The CCT_6 Mile & CCT_Lynx Creek sites were located on the Confederated Tribes of the Colville Reservation within the Kettle Mountain Range. The Kalispel, Indian Creek site (KAL_IC) was located in the Selkirk Mountains. The

CDA_A567 and CDA_Chet5 sites are on the lands of the Coeur d'Alene Tribe within the Coeur d'Alene Mountains. Sites range in elevation from 2200 to 3800 ft with annual precipitation ranging from 15in to 30in. All sites consist of mixed conifer consisting primarily of Ponderosa Pine (*Pinus ponderosa*), Douglas fir (*Psuedotsuga menziesii*), western larch (*Larix occidentalis*) and white pine (Pinus *monticola)*. Between 2016 and 2017 sites were harvested and planted based on individual tribal forestry plans.

Figure 2. A broad view map of timber site preparation study sites - shown in red stars – associated with the Upper Columbia United Tribes. The different Tribes' reservation boundaries in yellow. Insert map shows their ancestral lands.

Site Preparation treatments to reduce non-desired vegetation in the tribal sites consisted of backpack broadcast herbicide (7 plots), mechanical treatment (2 plots), and broadcast burning (4 plots). A control plot was located at each of the five study sites where no further vegetation control occurred after timber harvest. The management goal of mechanical and broadcast burn treatments is to reduce competing vegetation and expose approximately 50% mineral soils. Each site preparations and control treatments were approximately one acre in size.

At each treatment site two adjacent $10m^2$ survey plots were established. One plot was open to herbivory (open) and the second plot was surrounded by an 8ft herbivory exclusion fence (exclusion). The fence was constructed with 2 rows of 4ft woven field fence and steel 8-ft t-posts. A game camera was attached to the exclusion fencing and placed facing each adjacent open plot. Soil temperature loggers were placed 4-6in under the soil surface in the exclusion plot at three treatment sites.

CDA_A567 entered the study after the harvest of winter 2016/17, while the other sites KAl_IC, CCT_Lynx, CCT_6mi, CDA_chet5 after the winter 2017/18 harvest.

	Spray Date	Herbicides Applied
CDA_A567	June 2017	Velpar L
CDA_A567	June 2017	Glyphosate, Oust EX
CDA_Chet5	May 2018	Alligare, Imazapyr, Escort, Sly tac
CCT_6mi	April 2018	Alligare, Imazapyr, Escort, Sly tac
CCT_Lnyx	October 2018	Alligare, Imazapyr, Escort, Sly tac
CCT_Lnyx	April 2018	Alligare, Imazapyr, Escort, Sly tac
KAL_IC	April 2018	Alligare, Esplanade, Perspective

Table 1. Chart showing treatment sites, dates herbicides applied, which herbicides were used and respective tribe(s) that each treatment site pertains to.

Tree species and planting density were determined by each tribe and harvest location. The general stocking rate for each tribe was 350-400 trees per acre. CDA_A567 was replanted with larch and ponderosa, CDA_6mi was stocked with ponderosa, both CCT_Lynx and CDA_Chet5 were stocked with larch, and KAL_IC was stocked with white pine and larch.

Data Collection

Tree surveys occurred each April when trees were easier to see before herbaceous and grass species put on substantial growth. The height and species for each tree in the 10x10m survey plot was recorded along with whether it was crop or natural regeneration. Planted crop trees where flagged during the first year of surveying soon after planting.

Vegetation surveys took place between the last two weeks of June and first two weeks of July. Sixteen 1x1m sampling quadrats were surveyed at each 10x10m plot. Daubenmire cover classes were assigned to each species within the quadrat along with the substrate classes of litter, bare ground and coarse woody debris greater than 3in. The height in cm of the tallest of each plant species was recorded. Plants were identified to species and classified by form: tree, shrub, introduced forb, native forb, introduced grass, and native grass (USFS Plant Database, 2020).

Game cameras were checked once a month from April to November based on site accessibility. SD cards and batteries were swapped in the field during each visit. Ungulate visits were recorded by number, species and date and logged with the sampling timeframe. New individual visits were recorded when it was clear there were different individuals of the same species (example buck v. doe) or if there was a gap of over three hours between camera triggers.

Data Analysis

Average vegetation form and native status along with substrate cover was calculated by year and treatment. Tukey tests were conducted to determine statistical significance ($p<0.5$) between native and introduced forbs at year three. Tukey tests were also performed on shrub height comparisons from plots open to and plots excluding herbivory. Additional multivariate tests will further investigate differences between treatments specifically for forbs and shrub composition.

Camera visits by ungulates at treatment sites were recorded by total visits of ungulates during active camera periods and calculated as probability of a species using a treatment on any given day.

Results

Industrial Site Photo Points & Observations

Twelve industrial sites were documented from 2016-2020 with herbicide applications from 2012 (n=1), 2014 (n=3), 2015 (n=3), and 2016 (n=5). The most common herbaceous species at all these sites were introduced species, considered noxious weeds in Washington including Canada thistle (*Cirsium arvense),* St. John's wort (*Hypericum perforatum),* (prickly lettuce (*Lactuca serriola*), spotted knapweed (*Centaurea stoebe*), oxeye daisy (*Leucanthemum vulgare*), and common mullein (*Verbascum thapsus*). Although there where shrub components at sites treated in 2015 as well as before these were not the dominate cover class. Canopy closure was not reached at any site observed but at the site treated in 2012 had crop trees reaching 15ft.

See Appendix 1 for Industrial Site Photo Points & Observation.

Soil Temperature and Substrate Change

Average subsoil temperature, 50 F, were similar across sites and treatments. Daily variability was detected, more so above ground, but were not significant.

Average total substrate cover (including bare ground, litter, and coarse woody debris) was highest during year one at the burn site preps (57.0%), mechanical site prep (61.3%) and the control site (33.9%). Substrate cover was relatively high during year two and three at the herbicide site prep 59.2 and 38.6% respectively. Substrate cover was also relatively high during year three at the burn site prep 44.1%, while substrate cover reduced at the mechanical site prep and control to 27.5 and 31% respectively.

Bare ground exposure in the broadcast burn treatment had the most reduction throughout the 3 years from an average cover of 40 to 23%. The average bare ground exposure of herbicide treatments remained near 25% for the entire study. Comparatively, the average bare ground exposure of the control and mechanical treatments remained constant and did not go over 15% during the study.

Litter cover remained comparatively high at the herbicide sites over the 3 years 34%-46%. Litter cover at the mechanical treatments was initially high (55%) but reduced to near 25% by year two. Litter in the broadcast burn treatment continued to reduce over the span of the study from 33 to 23%. The control treatment had constant litter cover over the 3 years at 27%.

Average coarse woody debris (CWD) across treatments was relatively low compared to other substrate types, ranging from 14-21% over all three years. Compared to other site prep, the herbicide treatments had greater cover of CWD during year one and two, 18 and 20%, but decreased to 14% by year three. CWD had increases in two treatments in year three, 18% in broadcast burn and 15% in control treatment.

See Appendix 2 for graphs showing soil temperatures and substrate changes.

Vegetation Composition

The average cover for trees was below 1.3% over the three years at all UCUT treatments sites.

Grass suppression during the three years was greatest at the burn site preparation with 5.5, 9.7, and 9.7% cover, respectively. Compared to other site preps, grass cover was initially high at the herbicide treatment at year one (24.8%) but by year two and three it had reduced to 13.1 and 11.8%, which was below mechanical site prep at 22.0 and 18.4% cover and control at 27.8 and 21.8% cover.

Forb suppression was greatest at the herbicide and mechanical treatments with percent covers at years three at 21.8% and 16.5%. Forb cover was highest at the broadcast burn treatment, around 40% for year one and two, but was more similar to control cover by year three at 30% burn and 28% control.

At most years and treatments native forb cover was higher than introduced. This was not the case for the mechanical treatment where although total forb cover was low, native and invasive forb cover was similar in year two (10.4% native, 9.4% introduced) and year three (7.5% native and 8.5% introduced).

Shrub suppression was greatest at year one at the broadcast burn and mechanical site preps during the first year at 9.4% and 13.5%. Shrub cover at the control treatment remained relatively level throughout the study; 27.2, 23.8, and 30.1%. Shrub cover at the broadcast burn (27.6%) became similar to the control shrub cover by year three. Shrub cover increased at broadcast burn and mechanical sites during year two and three; 22.4 to 27.6% and 45.1 and 49.3% respectively. The herbicide site preparation was the only treatment where shrub cover decreased each year of the study from 21.5% in year one to 20.5% in year two and 16.9% in year three.

Species Richness and Diversity

Species richness did not vary greatly between treatments ranging from a high in year one 49 species after the mechanical treatment to a low of 32 species in year three after the herbicide treatment. Among all treatments there was a decline in richness from year one to three. During year three, native forb richness was much great than introduced. With the biggest difference occurring at the control site with 51 native species and 16 introduced while the mechanical site had the smallest difference in richness; 28 native and 9 introduced. During year one, diversity was similar between treatments, but by year two and three the control had higher diversity than any other treatment.

Shrub Height in the Open Plots vs the Exclusion Plot

There were significant differences ($p<0.05$) in shrub height in plots open to herbivory versus plots excluding herbivory indicting the occurrence of browse in altering shrub heights. At year three there was no significant difference in shrub height between the control's open and exclusion plots, 39.1cm and 33cm respectively ($p= 0.98$), nor herbicide treatment's open plot at 27.8cm and enclosure plots at 30.5cm ($p=0.72$). In the burn and mechanical site prep there is a marked increase in height in the plots excluding herbivory from year one to three, 19.8 to 61.3cm and 30.3 to 66.4cm respectively. The largest height difference occurred at year three at the broadcast burn treatment with an average shrub height of 40cm in the open versus 66cm in the exclusion plots ($p=0.015$).

Tree Heights and Survival

Average tree height increased more significantly at broadcast burn site prep (26.5, 32.5, 41.2cm) and control sites (no vegetation suppression) sites (20.4, 35, 40.7cm). By year 3, average tree height was greatest at those aforementioned sites compared to herbicide and mechanical site preps. There was little change in tree height between year two and three at herbicide site prep (31.5 to 33.9cm) and mechanical site prep (29.1 to 29.3cm).

Tree survival from year two to year three was similar between the herbicide, mechanical site prep and no site prep treatments, averaging 64.8, 64.3, and 65% respectively. Survival was highest at the burn site prep with 72% surviving from year two to three.

See Appendix 3 for Vegetation Composition graphs.

Ungulate Use at Treatments

Ungulate probability ranged by site from 3% to 60.2% likelihood of use on any given day. There was no comparison at CCT_Lynx between control and herbicide treatments due to no animal triggers during camera periods, which was not unusual, and malfunction of the camera settings. At the other four sites ungulate use was higher at non herbicide site prep sites. At CDA_A567 mechanical site prep had the highest usage with 21.8% probability compared to 13.1% at the herbicide treatment which was slightly lower than the broadcast burn probability at 14%. Although ungulate use was low at CDA_Chet5 compared to other study sites, control was the most visited at 6.8% compared to the herbicide site prep at 3.4%. CCT_6mi had a considerable difference in ungulate use at the broadcast burn (24.2%) compared to the herbicide site prep (8.2%). KAL_IC had the highest use of any study site with ungulates visiting the mechanical site prep at a rate of 60.2% compared to under half the use at the herbicide site prep with 27.1%.

See Appendix 4 for Ungulate Use Graphs.

Discussion

Early successional forest vegetation, whether produced by natural disturbance regimes or anthropogenic means, are crucial habitat for ungulate forage availability, particularly deciduous shrubs and native forbs (Hobbs 1996, Augustine & McNaughton 1998; Rose et al 2006, Cook et al., 2013; Berry et al., 2016). As the forest canopy closes these shade-intolerant plants become increasingly less abundant (Taylor, 2013; Ulappa et al., 2020). In recent decades there has been a decline in ungulate forage in western forests due to fire suppression, decline of public land harvesting, and intensive forest management practices (Spies et al., 2007; Swanson et al. 2011, Cook et al. 2016).

The forest management goals for the Upper Columbia Untied tribes include economical gains through timber harvest but also to maintain habitat for important game species and supporting a diverse native vegetation structure. The type of site prep used to enhance crop tree survival and growth is an important component in a holistic management strategy.

Weeds can alter ecosystem pathways including decomposition rates, hydrology, natural disturbance regimes, and successional pathway (Vitousek 1986, Hobbs & Huenneke 1992; Covington et al., 1994). Although there is a strong potential for exotic species to invade after logging and site prep (Vitousek et al. 1996; Chornesky et al., 2005), we found that native vegetation remained dominant at all treatments. Native forbs had greater overall cover at all treatment except the mechanical site prep where native shrub cover may have attributed to the overall reduction in forb cover. The lack of introduced species composition may reflect tribal management practices that can differ from intensive management practices or that past management has prevented the establishment of weed seed banks. This is in contrast to the visual observations documented in our photo survey conducted on 12 industrial sites in the region, where even after 7 years post-harvest, aggressive non-native species dominate the understory. Although only a snapshot of the effect of herbicide treatment on industrial lands in our region, UCUT mangers believe that these sites represent a much larger impact. Tribal staff work in the forests throughout the UCUT territory and report that the observations we made in this study reflect what they see on the ground throughout the region. There are sites in this region that received herbicide applications up to 15 years ago that we could not properly document for this study but where the impacts appear to persist until canopy closure. Additional monitoring of both study site and industrial photo surveys could help confirm these potential long-term impacts.

Site preparation treatments can have a strong influence on early successional vegetation communities. The use of herbicides particularly can diminish nutritional value by removing of key deciduous shrub species. These affects to vegetation structure can last over 10 years or until canopy closure is achieved (Edenius et al., 2013; Geary et al., 2017; Ulappa et al., 2020). One reason intensive forest practice include herbicides is to reduce crop tree rotations, but this can shorten successional stages, compressing the time between harvest and canopy closure (Visscher & Merrill, 2009; Swanson et al., 2011; Thompson, 2010, Demarais et al., 2017).

Although this UCUT study only looked at the first 3 years of stand establishment, it found greater suppression of deciduous shrubs in the herbicide treated sites. Herbicide treated sites had 16.9% shrub cover at year three compared to broadcast burn at 27.9%, mechanical site prep at 49.3%, and no site prep at 30.1% shrub cover. Other studies have found a 50–70% reduction in cover of palatable woody plant species with herbicide application which may directly reduce browse availability, but also may indirectly alter the abundance of forbs and grasses (Freedman et al., 1993; Stein, 1999; Maguire et al., 2009). It has also been noted that in sites with intensive forest management that include herbicides, shrubs only start to recover two years after application and will become a more dominant cover class until canopy closure, 12-15 years post treatment (Morrison & Meslow, 1984 and Harrington et al., 1995).

Strong and Gates (2005) found that five years after clearcutting sites with no herbicide treatment had 18- 48% greater winter forage value and herbicide treatment reduced summer elk forage. Whereas, Ulappa et al. (2020) found the use of herbicides reduced the amount of understory biomass and decreased the daily digestible energy intake of black-tailed deer (*Odocoileus hemionus columbianus)* for first 3 years after application.

In the first 3 years after stand establishment this UCUT study showed that site preparations of broadcast burn and mechanical techniques encourage shrub growth, while site prep with broadcast burn produced both abundant cover of shrubs and native forbs. These early successional vegetation structures can last several decades in site preps treatments that do not use herbicides (Halpern & Franklin, 1990).

Stokely et al. (2019) found ungulate browse on sites with different levels of herbicide application but did not look at alternative site prep that did not rely on herbicide. We found ungulate use lowest on sites prepared with herbicide. Stokely et al. (2019 & 2020) also found that there was increase crop tree browse damage on sites with herbicide applications that mimicked those of intensive management practices as opposed to sites with lower herbicide application containing higher vegetation diversity.

Ensuring crop tree growth and survival is essential in any forest management plan. We found the greatest survival of crop trees in site preps with a broadcast burn. Our findings did reflect similarly to those of Bai et al. (2012) which found little difference in survival rates of crop trees in herbicide site prep vs mechanical site prep. Although they state that crop tree growth response to treatment will be negligible over time (Bai et al. 2012), we found tree heights to be greater in sites with no site prep and in areas prepped with broadcast burning.

Making comprehensive forest management plans also need to account for ungulate interactions and supporting diverse early successional forests. Recent research has found that maintaining plant diversity during the first few years of stand establishment can help reduce the negative effect of ungulate browse on crop trees establishment (Gill 1992; Gill & Beardall, 2001; Beguin et al., 2016, Stokey et al., 2018; Stokey et al., 2019). Also, restoration and reforestation practices that mimic natural disturbance regimes through prescribed burns and thinning can increase diversity and productivity in drier forest ecosystems (Covinton et al., 1997; Harrod, 2001).

Although this study only investigated the various site preparation techniques during the first three years of stand establishment it can help guide tribal and regional managers in methods that can both foster tree survival and growth as well as providing optimal forage availability for ungulate species and maintaining many ecosystem functions of early successional forests. To better understand nutritional availability of browse further research can compare forage quality of individual species that occupy the early successional sites. Some research has documented that regardless of site preparation vegetation composition becomes similar in 5-7 years (Peter & Harrington, 2018) while other research suggests that site prep treatments can have long lasting effects (Dryness, 1973; Strong & Gates, 2005; Demarais et al., 2017). Continuing this research for several years until vegetation composition shows no effect of different site prep treatments will give a clearer picture of how long these treatments can affect early successional forest, stand establishment and impacts on ungulate browse.

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