AN ABSTRACT OF THE THESIS OF

Bethany L. Muñoz for the degree of Master of Science in Forest Resources presented on June 20, 2013.

Title: Influence of Silvicultural Treatments, Overstory, and Understory Vegetation on Quaking Aspen (*Populus tremuloides*) Regeneration in Southeastern Idaho.

Abstract approved:

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Quaking aspen (*Populus tremuloides* Michx.) is known to be a widely distributed, shade-intolerant and short-lived hardwood found in both seral, even-aged and stable, uneven aged stands. There have been reports of extensive aspen mortality, crown thinning, and branch dieback across North America that have been linked to the occurrence of severe droughts since 2001-2002. Because of reports of low aspen regeneration across the Intermountain West, as well as predictions of increases in aspen regeneration in the Northeastern US, researchers and land managers have now focused on managing aspen stands under the assumption that there are multiple aspen types. They have focused on improving resilience within quaking aspen stands with changing ecological conditions. For this thesis I focused on a project the Bureau of Land Management (BLM), Pocatello Field Office initiated in part to improve aspen restoration and resilience of stands in Soda Springs, ID. The BLM conducted two

mechanical removal treatments: cut and pile, and slash/lop and scatter. In addition several sites were broadcast burned to reduce fuel loads and conifer density, to enhance aspen regeneration and improve aspen stand resilience. According to the Soda Springs Hills Fuels Reduction and Ecosystem Restoration Environmental Assessment (EA), the BLM aimed to meet the objective of 2500 quaking aspen suckers per ha (1000 suckers per ac) within the two years following treatment, an index of treatment adequacy.

My primary objective for this thesis was to assess the influence of each silvicultural treatment, including the change in overstory and understory vegetation, on regeneration of aspen. Mean aspen regeneration two growing seasons after treatment was 11,532 suckers/ha on sites that received slash/lop and scatter treatment, followed by broadcast burning. With these high levels of suckering, there were also low densities of residual overstory conifers ($\leq$ 4 trees/ha with a basal area $\leq$ 2 m^2/ha). In comparison, sites that received the cut and pile treatment followed by a broadcast burn had a mean aspen regeneration of 44 suckers/ha, with higher densities of overstory conifers ($\geq$ 32 trees/ha with a basal area $\geq$ 26 m^2/ha). In slash/lop and scatter treatments without burning, sucker densities were as high as 1117 suckers/ha with low densities of conifers (0 trees/ha). In comparison, the site that received the cut and pile treatment without burning had an aspen regeneration of 0 suckers/ha, with a high density of conifers (36 trees/ha with a basal area of 47 m^2/ha).

Overall, sites with low residual overstory cover of large conifer trees (< 4 trees/ha), regardless of the treatment, had higher sucker densities two growing seasons after treatment (6244 suckers/ha, on average) than those seen in sites with a remnant overstory of >16 trees/ha (29 suckers/ha, on average). Also, sites that were burned, regardless of the mechanical treatment used, had higher sucker densities (11,244 suckers/ha) than those seen in sites that were not burned (576 suckers/ha). When comparing aspen sucker densities to competing understory woody cover following mechanical treatment, aspen sucker density was lowest (411 suckers/ha) on the site where both tree and shrub percent cover were highest (10 and 16%, respectively). Suckering appeared to be positively correlated with grass cover, however, with as high as 1117 suckers/ha growing with a high percentage of grass cover (≥ 26 %), on sites measured for change in understory following mechanical treatment.

Results were collected on a small number of sites and thus have limited statistical significance. However, we are confident that observed trends have values for managers. We suggest that transects should continue to be monitored to observe the long-term effects of silvicultural treatments on overstory and understory vegetation, which are likely to be influenced by climate variability and other disturbances into the future.

Influence of Silvicultural Treatments, Overstory, and Understory Vegetation on Quaking Aspen (*Populus tremuloides*) Regeneration in Southeastern Idaho

by
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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Bethany L. Muñoz, Author

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Lastly, but certainly not least, I would like to thank my family and friends who have supported me during the challenging, but rewarding process of working towards a Master of Science degree in Forest Resources. Thank you all!

CONTRIBUTION OF AUTHORS

John D. Bailey assisted with the writing of Chapters 1 and 2.

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DEDICATION

I would like to dedicate this thesis in memory of my grandmother, Naomi Ruth Medlock, and my grandfather, Donald Lee Brown.

Influence of Silvicultural Treatments, Overstory, and Understory Vegetation on Quaking Aspen (*Populus tremuloides*) Regeneration in Southeastern Idaho

CHAPTER 1 – INTRODUCTION

Quaking aspen (*Populus tremuloides* Michx.; referred to as aspen throughout the rest of this thesis) is known to be a widely distributed (Little, 1971; Perala, 1990), shade-intolerant (Kobe and Coates, 1997) and short-lived (Hessl, 2002) hardwood (Jones and Schier, 1985) found in both seral, even-aged and stable, uneven aged stands (Shinneman *et al*., 2013). Seral aspen stands are dependent upon disturbance for regeneration (Landhausser *et al*., 2010) whereas stable stands contain dominant aspen that have been persistent for more than 150 years (Rogers *et al*., 2013). Despite its wide distribution, aspen only makes up a small portion of forests in the Intermountain West (DeByle and Winokur, 1985; Brown, 1985; Perala, 1990). Benefits of healthy aspen stands include reducing fire severity and intensity by acting as a natural fire break (Kilpatrick *et al*., 2003), promoting plant and wildlife diversity (Mueggler, 1989; White *et al*., 1998), maintaining water quality and yield within watersheds, as well as providing valuable wood products (Kilpatrick *et al*., 2003) such as fuelwood and flakeboard (Mueggler, 1989). Since 2002, there have been reports of aspen decline, or dieback (Hanna and Kulakowski, 2012; Worrall *et al*., 2013) due to current land use management and changing ecological conditions, such as the rising occurrence of early, warm spring temperatures (Westerling, 2006). Low regeneration of aspen has also been attributed by conifer encroachment due to fire suppression

(Wall *et al*., 2001), increased ungulate herbivory (Baker *et al*., 1997; Suzuki *et al*., 1999; Kay and Bartos, 2000; Bailey and Witham, 2002), grazing by livestock (Mueggler, 1989), increase in shrub and herbaceous succession (Kilpatrick *et al*., 2003; Donaldson *et al*., 2006a; Landhausser *et al*., 2007; Mundell *et al*., 2007), drought stress, frost damage, disease (Worrall *et al*., 2013), further exacerbated by fire suppression (Kilpatrick *et al*., 2003; Shinneman *et al*., 2013). Because of reports of low aspen regeneration across the Intermountain West (Worrall *et al*., 2013), as well as predictions of increases in aspen regeneration in the Northeastern US (Iverson *et al*., 2008), researchers and land managers have now focused on managing aspen stands under the assumption that there are multiple aspen types, and have focused on improving resilience within quaking aspen stands with changing ecological conditions (Rogers *et al*., 2013).

Though the primary method of aspen regeneration is via root sprouting or "suckering", it also regenerates through sexual reproduction (Mock *et al*., 2013). Mock *et al*. (2008) found that sexual reproduction was important to increasing genetic diversity within aspen, indicating that some aspen clones may not be as old as reported. Sexual reproduction of aspen is possible if there is an occurrence of a fire that is severe enough to promote the exposure of mineral soil, there are fertile aspen populations within the proximity, and there is a presence of adequate moisture (McDonough, 1979; Kay, 1993; Romme *et al*., 1997). Suckering is permitted when apical dominance within mature aspen is slowed or halted, either naturally or by disturbance due to an increase in cytokinin and a decrease in auxin (Peterson, 1975; Schier and Smith, 1979). This process can naturally occur when soil temperatures increase during the growing season of aspen (late April – late September; DeByle and Winokur, 1985) or after a disturbance, such as fire, interrupting the growth of mature aspen. Fraser *et al*. (2002) found that soil temperatures $\geq$ 12°C (53.6°F) stimulate aspen suckering. However, prolific suckering occurs after a disturbance with minimal increases in soil temperature, so they suggested that other environmental factors, besides increased soil temperatures, stimulate sucker growth. They observed that increasing levels of calcium and nitrogen contributed to an increase in growth rates and dry mass of aspen. These nutrients are typically found within Mollisols, which support stable aspen stands (Amacher *et al*., 2001), in comparison to Alfisols, which are found primarily under conifer dominated stands (Cryer and Murray, 1992; Amacher *et al*., 2001). However, soil temperatures, light and nutrient availability are decreased due to shading of the overstory and understory.

Gradowski *et al*. (2010) observed that colder soil temperatures under conifer overstory had a negative effect on aspen regeneration. Mixed aspen/conifer stands with more than 50% conifers have lower soil temperatures due to a litter layer consisting of branches in various levels of decomposition and conifer needles (Amacher *et al*., 2001) as well as a result of significant shading from the overstory (Messier *et al*., 1998; Calder *et al*., 2011). In addition to promoting the transition from Mollisols to Alfisols under conifer encroached aspen stands decreasing the stability of aspen (Amacher *et al*., 2001), reduction of light in mixed and dominant conifer stands also reduce the likelihood of mycorrhizal infection of aspen roots, further inhibiting nutrient uptake and therefore, limiting aspen regeneration (Clark and St. Clair, 2011).

Aspen Decline

Since stand productivity and spatial variation of aspen depend on moisture and temperature (Worrall *et al*., 2013) the occurrence of drought decreases the distribution and productivity of aspen stands (Michaelian *et al*., 2011). Hogg *et al*. (2008) found more than a two-fold increase in aspen stem-mortality regionally in Canada following the 2001-2002 drought. It was estimated that about 3.2 million ha of aspen decline was detected in North America from 2000-2010 (Worrall *et al*., 2013). It has also been predicted that aspen distributions will move upwards in elevation with climate change (Rehfeldt *et al*., 2009). Within the US Forest Service's Rocky Mountain Region, it was predicted that the distribution of aspen will migrate a distance of 250 m by 2030, 400 m 2060, and by 750 m in 2090, while decreasing in cover (Rehfeldt *et al*., 2009). It was estimated that 26% of the current distribution of aspen will no longer be suitable for aspen growth by 2060 (Iverson and Prasad, 1998; Hamann and Wang, 2006; Iverson *et al*., 2008; Rehfeldt *et al*., 2009; Gray and Hamann, 2012; Worrall *et al*., 2013). Worrall *et al*. (2013) predicts that the drivers of this aspen decline could be observed through the following factors in order of importance: (1) mean maximum temperature of the warmest month in a year, (2) precipitation April throughout September, (3) the differential of summer to winter temperatures (mean temperature of warmest month – mean temperature of coldest month), (4) temperatures found from November through February, (5) > 5°C (41°F) degree-days, and (6) mean annual precipitation. They further predicted that there will continue to be a decline of habitat to the south with increases in aspen habitat to the north.

Though drought has been linked to the decline of vigor and growth in aspen (Hogg *et al*., 2008; Worrall *et al*., 2013), changing disturbance and climate regimes may favor aspen over conifers in seral, co-dominant stands (Kulakowski *et al*., 2013). Coupled with a change in temperature and precipitation regimes (Dutzik and Willcox, 2010), widespread bark beetle outbreaks in conifer stands (Kulakowski *et al*., 2003) throughout western North America may favor aspen dominance over conifers (Raffa *et al*., 2008). Aspen dominance may also be further promoted as the occurrence of wildfires increases due to increased drier and warmer conditions throughout the West (Westerling *et al*., 2006).

Herbivory

Other impacts that cause decline in aspen include ungulate browsing (Seager *et al*., 2013) and livestock grazing (Mueggler, 1989). More specifically, persistent herbivory on aspen suckers can lead to stand senescence and regeneration failure because aspen is a short-lived species (Hessl, 2002). This can further decrease the resilience of aspen ecosystems (Holling, 1973) as well as negatively impact the functional, genetic, and structural diversity of aspen stands (Seager *et al*., 2013). Resilience of aspen stands is compromised when there is an occurrence of constant browsing on young-aged aspen cohorts (Worrall *et al*., 2008, 2010). As a primary method of defense against insect herbviory (Hemming and Lindroth, 1995), aspen uses chemical defenses, phenolic glycosides and condensed tannins (Lindroth and St. Clair, 2013). These chemical defenses are found at higher levels in young aspen suckers (Donaldson and Lindroth, 2007; Smith *et al*., 2011b). However, it is uncertain about their ability to control ungulate browsing (Seager *et al*., 2013). In addition to chemical defenses, aspen also can escape from herbivory through rapid vertical growth. However, these defenses are minimized with low nutrient and light availability (Donaldson *et al*., 2006b; Osier and Lindroth, 2006). Calder *et al*. (2011) found that because these defenses are minimized when aspen stands are encroached by conifers, which reduce light and nutrient availability, susceptibility to browsing is increased.

Though it has been found that browsing can increase post-fire in elk winter ranges where regeneration of aspen was decreased (Bailey and Witham, 2002; Hessl and Graumlich, 2002), there have also been instances where large-scale fires have dispersed ungulates, thus minimizing the impacts of browsing on aspen suckers (Bartos and Mueggler, 1980; Smith *et al*., 2011a) where regeneration of aspen was successful. Seager *et al*. (2013) suggested that to further promote resilience within aspen stands, managers should direct their attention to regeneration and survival of aspen seedlings, suckers, and young ramets, through release from ungulate herbivory.

This could be accomplished through means of disturbance and through introduction of an apex predator. Other methods used to deter ungulate herbivory include the use of jackstraw, the interlacing of harvest debris, which impedes the movement of ungulates and can permit the release of some aspen suckers to further promote regeneration of aspen into the overstory (Halofsky and Ripple, 2008; Seager, 2010).

Improving Aspen Regeneration and Aspen Resilience

In order to increase aspen regeneration, as well as improve the resilience of aspen communities, land managers have used mechanical treatments and prescribed burns that mimic natural disturbances, individually and in combination, within aspen stands (Kilpatrick *et al*., 2003; Bates *et al*., 2006; Collins *et al*., 2011; Krasnow *et al*., 2012; Shinneman *et al*., 2013). These treatments in combination have been reported to be the most efficient in reducing fuel loads (Martinson *et al*., 2013) and reducing conifer encroachment into aspen stands. It has been determined that conifer encroachment has been expanding since the late 1800s (Tausch *et al*., 1981; Miller and Tausch, 2001; Wall *et al*., 2001), and has been the leading cause to a 60% decline in aspen landscapes on national forests throughout Utah (Bartos and Campbell, 1998).

Though further research is needed to determine the rate of conifer encroachment, Johnson and Miller (2006) found that increased woodland development begins once stands reach 50 years of age, sooner with increasing elevation and northerly exposure. It was also found that aspen stands throughout the northern Great

Basin with elevations < 2,100 are at risk as conifers are rapidly replacing them (Wall *et al*., 2001; Bates *et al*., 2006). To reduce conifer encroachment and take advantage of natural aspen regeneration, mechanical conifer removal (Collins *et al*., 2011) treatments, some followed up with prescribed burning (Bates *et al*., 2006), have been conducted to increase light and nutrient availability (Jones *et al*., 2005). Aspen have a lower leaf area index than conifers. As a result, light availability is high in both stable dominant and decadent aspen stands (Messier *et al*., 1998; Powell and Bork, 2006), which contribute to the high biodiversity in aspen stand understories (Hart and Chen 2006; Kuhn *et al*., 2011). Water availability is also increased with low leaf area index as snow is permitted to accumulate below stands during winter (Buck and St. Clair, 2012). In addition to conifer removal, mature aspen have also been clearcut (Bartos and Mueggler, 1982; Smith *et al*., 1972) and/or burned (Bartos, 1979; Bartos and Mueggler, 1981; Brown and Debyle, 1987; Romme *et al*., 1995; Smith *et al*., 2011a) to stimulate suckering from the roots.

Given a newer focus of improving resilience within aspen stands as well as understanding that there are multiple aspen types that respond differently to treatments and climate change, public agencies have engaged in management practices that benefit aspen regeneration, as well as reduce fuel loads, in order to promote aspen resilience and decrease the risk of severe wildland fire (USDI, 2005).

Southeastern Idaho Study Site

Because of the potential threat of wildland fire on the Soda Springs community, the town was categorized as an "at risk community", as part of an effort to reduce hazardous fuels and restore forest rangeland health under the 2001 National Fire Plan. Public Law 108-148 Healthy Forests Restoration Act of 2003 (HFRA) was created in response to the 2002 Healthy Forests Initiative (HFI). The HFI mandated improvement in reducing of the risk of large and/or severe wildland fires through the Departments of Agriculture and Interior, and the Council on Environmental Quality. Projects centered on reducing hazardous fuels and restoring forests and rangelands within federal lands at risk of wildland fire or insect and disease epidemics. As part of the Community Wildfire Prevention Plan portrayed in the HFRA for Caribou County, Idaho, the 2004 Caribou County Wildfire Mitigation Plan was produced. The Soda Springs Hills Fuels Reduction and Ecosystem Restoration Project was identified as an "authorized hazard reduction project" rated as a high priority action. Preliminary planning for the project was initiated in 2003 by the United States Department of Interior Bureau of Land Management (BLM). Primary management goals were to reduce fuel loads, improve rangeland and forest health, and to restore disturbances to natural levels. Treatments included, but not limited to: (1) conducting cut and pile mechanical treatments, with the goal of reducing fuel loads and conifer density; and (2) conducting slash/lop and scatter mechanical treatments with the sole purpose of improving regeneration of aspen within seral mixed aspen-conifer stands on BLM-managed land in Soda Springs, ID. These mechanical removal treatments were intended to be followed up with a broadcast burn to further reduce fuel loading and stimulate suckering. However, these burns did not consistently make it into every aspen stand, possibly due to higher fuel moistures within these aspen stands (Brown and Simmerman, 1986; Smith *et al*., 1993), leaving slash behind. These aspects of the project made up only a portion of the entire Soda Springs Hills Fuels Reduction and Ecosystem Restoration project (USDI, 2005).

According to the Soda Springs Hills Fuels Reduction and Ecosystem Restoration Environmental Assessment (EA), the BLM aimed to meet the objective of 2500 quaking aspen suckers per ha (1000 suckers per ac) within the two years following treatment, an index of adequacy. This number is consistent with Kurzel *et al*., 2007 who considered stands with suckers exceeding 2500 stems/ha and had a height less than 1.5m tall, as self-replacing stands. However, a stand is considered at risk for decline in regeneration if sucker densities are less than 1235 suckers/ha, with heights less than 1.4 m tall (Mueggler, 1989). In addition to setting the biological threshold value for aspen regeneration, the EA further states that a fully regenerated aspen stand should provide suitable habitat for native plants and a suitable habitat for wildlife, as all as act as a fire break, consistent with the literature. Monitoring of the overstory, understory, and regeneration of aspen occurred before and after treatments during ensuing growing seasons. However, monitoring was not always conducted on the same sites annually.

Project Objectives

The objective of my thesis was to assess four case studies based on the array of treatments conducted by the BLM in an effort to reduce fire risk (by decreasing fuel loads and conifer density) as well as enhance aspen regeneration. First, because there were two mechanical removal treatments conducted prior to burning, one aimed to reduce fuel loads and the other to enhance the regeneration of aspen, I wanted to: (1) observe and compare aspen regeneration in burned sites post-treatment, (2) compare the two mechanical treatments, and (3) observe the impact of overstory retention on aspen regeneration. Secondly, I wanted to look at sites that were not burned, but received either mechanical treatment, and compare their respective aspen regeneration response to the overstory retention. Thirdly, I wanted to compare the difference in aspen regeneration between sites that were burned, regardless of prior mechanical treatment used, with sites that were not burned. Finally, on four sites that were monitored for both understory cover and aspen regeneration, but were only mechanically treated, I wanted to observe and compare understory vegetation response with aspen regeneration. Chapter 2 explains each of my objectives in more detail. The scope of inference for this thesis is limited to aspen stands on BLM-managed land within Soda Springs, ID.

CHAPTER 2 – INFLUENCE OF SILVICULTURAL TREATMENTS, OVERSTORY, AND UNDERSTORY VEGETATION ON ASPEN REGENERATION IN SODA SPRINGS, ID

ABSTRACT

In the face of potential decline in aspen stands throughout the Intermountain West, there is rising concern on the resilience of aspen stands. This study looked at differences between two mechanical removal treatments, cut and pile and slash/lop and scatter, used to improve resilience on sites containing aspen within Soda Springs, ID. Treatments were followed with a broadcast burn on some sites. The regeneration of aspen, overstory, and understory vegetation were monitored before and after each treatment. Aspen suckering was as high as 12,338 suckers/ha two growing seasons after treatment on sites that received the slash/lop and scatter treatment, followed by a spring broadcast burn, but only if overstory conifers had been removed. Where ≥ 16 overstory conifers/ha were retained, aspen suckering was limited to less than 88 suckers/ha two growing seasons after treatment. Suckering was also high on sites that received slash/lop and scatter, without burning. The number of suckers/ha two growing seasons after slash/lop and scatter without burning were as high as 1117 suckers/ha where the overstory was removed. All sites that were burned, regardless of the mechanical treatment used, had higher sucker densities than those seen in sites that were not burned. When comparing aspen sucker densities to understory cover following mechanical treatment without burning, we found low aspen sucker density

with higher percentage of shrub cover. Results were collected on a small number of sites and thus have limited statistical significance. However, we are confident trends have values for managers. We suggest that transects should continue to be monitored to observe the long-term effects of silvicultural treatments on overstory and understory vegetation, which are also influenced by climate variability.

INTRODUCTION

Aspen (*Populus tremuloides* Michx.) is known to be a widely distributed (Little, 1971; Perala, 1990), shade-intolerant (Kobe and Coates, 1997) and short-lived (Hessl, 2002) hardwood (Jones and Schier, 1985) found in both seral, even-aged and stable, uneven aged stands (Mueggler, 1989; Shinneman *et al*., 2013). Despite its wide distribution aspen only makes up a small portion of forests in the Intermountain West (DeByle and Winokur, 1985; Brown, 1985; Perala, 1990; Seager, 2010). With changing ecological conditions, there have been reports of extensive aspen mortality, crown thinning, branch dieback across North America (Worrall *et al*., 2013) that have been linked to the occurrence of severe droughts since 2001-2002 (Worrall *et al*., 2010; Michaelian *et al*., 2011). Low regeneration of aspen has also been attributed by conifer encroachment (Wall *et al*., 2001), increased ungulate herbivory (Baker *et al*., 1997; Suzuki *et al*., 1999; Kay and Bartos, 2000; Bailey and Witham, 2002), grazing by livestock (Mueggler, 1989), shrub and herbaceous succession (Kilpatrick *et al*., 2003; Donaldson *et al*., 2006a; Landhausser *et al*., 2007; Mundell *et al*., 2007), drought, defoliating insects, frost, disease (Worrall *et al*., 2013), and fire suppression (Kilpatrick *et al*., 2003; Shinnenman *et al*., 2013). Because of reports of low aspen regeneration across the Intermountain West (Worall *et al*., 2013), as well as predictions of increases in aspen regeneration in the Northeastern US (Iverson *et al*., 2008), researchers and land managers have now focused on managing aspen stands under the assumption that there are multiple aspen types, and have focused on improving resilience within quaking aspen stands with changing ecological conditions (Rogers *et al*., 2013). My study focused on managed aspen types found in southeastern Idaho and their responses to treatments that aim to mimic natural disturbances and improve aspen resilience.

Given a newer focus of improving resilience within aspen stands as well as understanding that there are multiple aspen types that respond differently to treatments and climate change, public agencies have engaged in management practices that benefit aspen regeneration, as well as reduce fuel loads to promote aspen resilience and decrease the risk of severe wildland fire. Due to the potential threat of wildland fire on the Soda Springs (Idaho) community, the town was categorized as an "at risk community." The Soda Springs Hills Fuels Reduction and Ecosystem Restoration Project was rated as an "authorized hazard reduction project" that called for immediate action. Preliminary planning for the project was initiated in 2003 by the United States

Department of Interior (USDI) Bureau of Land Management (BLM). Project necessity arose from the increased potential for intense severe wildland fire from high fuel loading adjacent to the Soda Springs community and the need to enhance mountain shrub and aspen regeneration due to observed declines in cover and vigor. Primary management goals of the overall project have been to reduce fuel loads, improve rangeland and forest health, and restore disturbances to natural levels. Treatments included, but were not limited to, conducting cut and pile treatments, with the sole purpose of reducing fuel loads and conifer density, as well as conducting slash/lop and scatter treatments with the sole purpose of improving regeneration of aspen within seral mixed aspen-conifer stands on BLM-managed land in Soda Springs, ID. Mechanical removal treatments were intended to be followed up with a broadcast burn to further reduce fuel loading and increase soil temperatures to stimulate suckering. However, these burns did not consistently make it into every aspen stand due to high moisture content within aspen stands, leaving slash behind. These treatment areas made up only a portion of the entire Soda Springs Hills Fuels Reduction and Ecosystem Restoration project (USDI, 2005).

According to the Soda Springs Hills Fuels Reduction and Ecosystem Restoration Environmental Assessment (EA), the BLM targeted the production of 2500 quaking aspen suckers per ha (1000 suckers per acre) within the two years following treatment (USDI, 2005). This number is consistent with Kurzel *et al*.

(2007) who considered stands with suckers exceeding 2500 stems/ha and had a height less than 1.5m tall, as self-replacing stands. To confirm the objective was met, monitoring of the overstory, understory, and regeneration of aspen on selected sites occurred before and after treatments during the growing season. However, monitoring was not always conducted at the same sites every year, nor was monitoring initiated the same year at different sites. BLM's assumption was that if 2500 suckers/ha were produced after treatment, then aspen would reduce fire severity and intensity by acting as a natural fire break (Kilpatrick *et al*., 2003), as well as promote plant and wildlife diversity (Mueggler, 1989; White *et al*., 1998), maintain water quality and yield within watersheds, and provide valuable wood products (Kilpatrick *et al*., 2003) such as fuelwood and flakeboard (Mueggler, 1989).

Based on the data available, my objective was to observe how the silvicultural treatments applied within the Soda Springs Hills Fuels Reduction and Ecosystem Restoration Project, in combination with the change in vegetative cover over time, had influenced aspen regeneration. My study was therefore designed to specifically answer the following research questions: (1) in combination with the change in overstory over time, how does the cut and pile treatment, followed by broadcast burning, differ from the slash/lop and scatter treatment, also followed by broadcast burning, in recruiting aspen underneath mixed aspen-conifer stands, (2) in combination with the change in overstory over time, how does the cut/pile and cover treatment alone differ from the slash/lop and scatter treatment alone, in recruiting aspen underneath mixed aspen-conifer stands, (3) how does applying broadcast burning on sites, regardless of the prior mechanical treatment applied, influence aspen regeneration, in comparison to sites that were not burned, regardless of the mechanical treatment applied, and (4) how does mechanical treatment alone influence aspen regeneration with change in understory. This study was conducted during the growing season in 2012.

METHODS

Study Area

The Soda Springs Hills Fuels Reduction and Ecosystem Restoration project is located on BLM land nearby Soda Springs, Idaho. Based on the Soda Springs Airport remote automated weather station (RAWS), the annual average maximum and minimum temperatures are 55.8 and 26.4ºF, respectively. The annual average total precipitation is 39.7 cm, and the annual average total snowfall is 127 cm reaching an annual average depth of 0.9 m. Aspen stands are intermixed with bigtooth maple (*Acer grandidentatum*), Rocky Mountain juniper (*Juniperus scopulorum*), and Douglas-fir (*Pseudotsuga menziesii*). The fire history within and outside the project area prior to 1980 is unknown. Wildfires within the past 33 years have not occurred within the nine sites containing aspen (Figure 2.1).

Overstory, Understory, and Aspen Regeneration Measurements

Nine sites were selected based on the boundaries of aspen stands experiencing decline and low vigor (Figure 2.2). Elevation of these sites ranged from 1927 m to 2017 m. Livestock allotments were located outside the sites monitored in this project. At each site, field crews established a single 30.5 transect for understory and aspen regeneration measurements placing rebar stakes into the ground at randomly-selected locations within these quaking aspen stands prior to treatment. Fixed-area plots were also set up at the beginning point of some transects for overstory measurements. Transects progressed from the rebar in a random direction roughly oriented along elevational contours and within the interior portion of each stand. Coordinates of the rebar and transect direction were recorded using a Global Positioning System (GPS).

Pretreatment measurements of the overstory, understory, and aspen regeneration (suckers/ha) were conducted within different years (Table 2.1). The number of aspen suckers was measured at each of the nine sites within 0.9 m on either side of the 30.5 m transect forming a 56 m^2 density belt. An aspen tree was considered to be a sucker when its height was < 1.4 m. Browsing was also recorded within this density belt by counting the number of suckers browsed out of the sum total of suckers counted within the density belt. At seven sites, the response of mature trees (overstory; trees/ha and basal area m^2/ha) and saplings (saplings/ha) was measured within an 11.4 m radius (0.04 ha) around the rebar stake, and the response of seedlings (seedlings/ha) was measured within a 3.5 m radius (0.004 ha) around the rebar stake. A mature tree was defined as a tree with a diameter at breast height (DBH) > 10.2 cm. A sapling was defined as a tree with a height > 1.4 m and a DBH ≤ 10.2 cm. A seedling was defined as a tree with a height ≤ 1.4 m. The understory was measured at four sites using a points-by-transect protocol along the 30.5 m transect. All species identified were then categorized into the following lifeforms: shrubs, grasses, and forbs/herbs. All dead material detected was categorized into litter. All species found using the points by transect protocol and mature trees, saplings, and seedlings found within fixed-area plots are listed in Appendix B.

Treatments

Each of the nine sites received one of two mechanical treatments, intended to be followed up with a broadcast burn either in the spring or fall, at least a year after mechanical treatment to allow drying (Figure 2.3). Treatments were applied on different years at different sites. In both mechanical removal treatments, almost all of both live and standing dead Douglas-fir with a DBH of ≤ 30.5 (≤ 40.6 cm in 2010), all live juniper, and 75% of standing dead aspen were cut. Felled trees with a DBH > 7.6 cm were limbed. Both mountain mahogany (*Cercocarpus ledifolius*) and larger Douglas-fir trees were reserved for wildlife purposes, as well as to help maintain a low fuel bed depth below 30.5 cm.

In order to reduce fuel loads and conifer density, a cut and pile (CP) mechanical treatment was used at three sites. After trees were cut, the lower portion of the pile consisted of a mixture of large tree boles and smaller vegetation placed directly on the ground. The remainder of the pile was constructed to size standards. All slash with a length < 0.6 m and a diameter < 2.5 cm or > 17.8 cm was left on the ground, not exceeding a height of 0.3 m. Piled slash had a length ≥ 0.6 m and a diameter between 2.5 and 17.8 cm. Piles were constructed in a triangular shape consisting of cut boles, stems, limbs, and other slash. To promote prompt ignition and aid in the combustion of larger slash, an area containing small slash, consisting of small branches with leaves and needles still attached and/or small branches with a diameter < 0.6 cm to 1.27 cm, was placed in the center of each pile. Piles were 1.8 to 2.1 m in diameter and were about 1.5 m in height. Unless specified, piles were not constructed within 7.6 m from a treatment unit boundary, and within 3 m from leave trees. Roadways, drainage ditches, logs or stumps, or within streams or channel bottoms, were not to contain piled slash.

The second mechanical treatment, slash/lop and scatter (SLS), was conducted for the sole purpose of enhancing aspen regeneration, at six sites. Slash was lopped into 1.2 m sections, and then scattered across the treatment unit creating an even fuel bed ≤ 30.5 cm in depth, enough to carry a fire to increase soil temperatures high enough to stimulate suckering. Higher temperatures were expected to promote aspen recruitment following a study by Fraser *et al*. (2002) who found that soil temperatures above 12°C (53.6°F) stimulate numerous aspen suckers.

Mechanical treatments occurred within units in 2008, 2010, and 2011 (Figure 2.3). Broadcast burns were set in spring of 2009, fall of 2011, and spring of 2012. However, only the broadcast burn set in the spring of 2009 affected four of the nine sites observed. The 30.5 cm fuel bed, consisting of slash from thinning/cutting treatments in 2008, was sufficient to carry a fire. Fire behavior was not measured; however, fire behavior was simulated for desired, high, and low prescribed burning conditions for that season using BehavePlus version 3.0.2 (2005).

Based on the daily RAWS station summary for the Grace, Idaho, located 23 km away from sites, the maximum and minimum air temperature for May 20, 2009 was 64 and 42ºF, respectively, for an average air temperature of 56ºF. Maximum and minimum fuel temperatures were 83 and 37ºF, respectively, with an average fuel temperature at 58.5ºF. Wind speeds averaged 13 km/h coming from West-Northwest. The maximum and minimum relative humidity was 55 and 23%, respectively, with an average of 35%. There was no precipitation during the broadcast burn. Consequently, we assume that fire behavior corresponded to conditions similar to those simulated under low conditions in BehavePlus version 3.0.2 (2005; Table 2.2).

Using the average wind speed of 13 km/h measured for May 20, 2009, possible fire behavior for the 2009 spring broadcast burn, simulated based on low conditions using BehavePlus version 3.0.2 (2005), were as follows (Table 2.3): surface rate of spread ranged from 0 – 171 m/h (0 – 8.5 ch/h), flame lengths ranged from 0 – 1.16 m (0 – 3.8 ft), scorch heights ranged from 0 – 2.13 m (0 – 7 ft), probability of mortality equaled out to 4%, and the probability of ignition from a firebrand ranged from 10 – 38%.

Observations and Data Analysis

All data were compiled in FEAT/FIREMON Integrated (FFI) version 1.04.02 (2012) and normalized per hectare. To address the first research question, I compared trends of aspen regeneration before and up to four growing seasons post-burn on four burned sites. Two sites received SLS prior to burning (SLSB), and another two sites received CP prior to burning (CPB). The purpose of this comparison was to determine whether the slash/lop and scatter treatment was effective in stimulating prolific suckering post-burn, compared to sites that were treated solely to reduce fuel loads and conifer density. I compared each trend of aspen regeneration to change in overstory, sapling, and seedling density, from pretreatment to four growing seasons after treatment.

In addressing my second research question, I compared trends of aspen regeneration on two sites that received SLS without burning, with aspen regeneration at one site that received CP without burning, before and two growing seasons after treatment. The purpose of this comparison was to observe if SLS was effective at stimulating more suckers than sites that received CP, both without burning, two growing seasons after treatment. I also compared changes in overstory, sapling, and seedling density between those sites.

My third research question was addressed by comparing mean trends in aspen regeneration in all the four sites that were burned, regardless of prior mechanical treatment (Thin-Plus-Burn), to the five sites that were not burned (Thin-Only), regardless of mechanical treatment. I wanted to observe whether the mean number of suckers/ha produced after burning was different than the mean number of suckers/ha produced after mechanical treatment. A Wilcoxon Rank Sum Test was then performed in R version 2.15.2 (2012) to detect evidence of difference before and two growing seasons after treatment (due to availability of data), between sites that were burned and sites that were not burned.

To address my fourth research question, I compared the number of suckers/ha among four mechanically treated sites that were measured for understory and aspen regeneration: FB37_Aspen_013, FB37_Aspen_015, FB37029, and FB37030. Due to availability of data, I compared change in understory cover with the change in number of aspen suckers/ha, before and two growing seasons after treatment.

RESULTS

Only four tree species were found in all fixed-area plots: quaking aspen, Douglas-fir, Rocky Mountain juniper, and Bigtooth Maple. Little to no evidence of browsing was found within any of the density belt transects. Mean aspen regeneration was higher in SLSB sites than in CPB sites through growing season 4 (Figure 2.4). Pretreatment mean aspen regeneration in SLSB was 426 suckers/ha, in comparison to a mean aspen regeneration in CPB sites of 309 suckers/ha (Table 2.4). Mean aspen regeneration two growing seasons after treatment was 11,532 suckers/ha at SLSB sites compared to 44 suckers/ha at CPB sites. Four growing seasons after treatment, mean aspen regeneration was 3247 suckers/ha in SLSB and 15 suckers/ha in CPB. As aspen suckers/ha increased at SLSB sites, both mature Douglas-fir and mature aspen density and basal area decreased. With the decrease in aspen suckers/ha post-burn at CPB sites, mature Douglas-fir density and basal area remained higher than that at SLSB sites and this trend continued until growing season 4, while mature aspen at CPB sites declined post-burn. There was little to no presence of mature Rocky Mountain juniper or bigtooth maple before or after treatment at both SLSB and CPB sites. Both Douglas-fir and Rocky Mountain juniper saplings decreased post-burn at both SLSB and CPB sites (Table 2.5). Though aspen regeneration was not found within the density belt measurements at site FB37TD016 in growing seasons 2-4, there were aspen saplings and seedlings (Table 2.6) found within fixed-area plots.

Mean aspen regeneration at SLS sites was higher than that found in CP sites (Figure 2.5). Pretreatment mean aspen regeneration at SLS was 823 suckers/ha in comparison to the CP site of 323 suckers/ha (Table 2.7). Two growing seasons after treatment, mean aspen regeneration at SLS sites was 955 suckers/ha in comparison to the CP site which had no suckers. Mature Douglas-fir density and basal area decreased with increases in mean aspen regeneration at SLS sites, whereas mature Douglas-fir density and basal area at the CP site remained higher than that at SLS sites and that trend also continued before and after treatment, with a decrease in aspen regeneration. All other mature tree species saw a decline post-mechanical treatment at both SLS and CP sites. There was a higher presence of bigtooth maple saplings than aspen saplings in growing season 2 (Table 2.8). Though aspen regeneration was not found within the density belt measurements at site FB37TD018, there were aspen saplings and seedlings (Table 2.9) within fixed-area plots.

The trend of mean aspen regeneration in the thin-plus-burn group was higher than the trend of mean aspen regeneration in the thin-only group (Figure 2.6). Pretreatment mean aspen regeneration in the thin-plus-burn group was at 367 suckers/ha (n=4) in comparison to the thin-only group at 564 suckers/ha (n=5) (Table 2.10). Mean aspen regeneration of the thin-plus-burn group in two growing seasons post-burn was 5788 suckers/ha, in comparison to the thin-only group which had a mean aspen regeneration of 576 suckers/ha. The Wilcoxon Rank Sum test showed no evidence of a difference in the median number of aspen suckers per ha before and two growing seasons after treatment among the thin-plus-burn and the thin-only groups (W = 12, p-value = 0.7302). The median of the difference between the thin-plus-burn and the thin-only group is estimated to be 4187 aspen suckers/ha (95% CI: -441, 13809).

Dominant species detected in pretreatment understory monitoring include: Sandberg bluegrass (*Poa secunda*), smooth brome (*Bromus inermis*), sticky purple geranium (*Geranium viscosissimum*), Fendler's meadow-rue (*Thalictrum fendleri*), Saskatoon serviceberry (*Amelanchier alnifolia*), mountain snowberry (*Symphoricarpos oreophilus*), quaking aspen (*Populus tremuloides*), and Douglas-fir (*Pseudotsuga menziesii*). Dominant species detected two growing seasons after mechanical treatment includes: pinegrass (*Calamagrostis rubescens*), blue wildrye (*Elymus glaucus*), sticky purple geranium, sweetcicely (*Osmorhiza berteroi*), mountain snowberry, white spirea (*Spiraea betulifolia*), bigtooth maple (*Acer grandidentatum*), and quaking aspen. When comparing aspen sucker densities to competing understory woody cover following mechanical treatment, aspen sucker density was lowest (411 suckers/ha) on the site where both tree and shrub percent cover were highest (10 and 16%, respectively). Suckering appeared to be positively correlated with grass cover, however, with as high as 1117 suckers/ha growing with a high percentage of grass cover (≥ 26 %), on sites measured for change in understory following mechanical treatment (Table 2.11).

DISCUSSION

Overstory conifer removal is integral to stimulating aspen suckering in sites located on BLM-managed land in Soda Springs, ID. Consistent with Kilpatrick *et al*. (2003), Seager (2010), Collins *et al*. (2011) Krasnow *et al*. (2012), aspen sucker density in this study was strongest, two growing seasons after treatment, in areas that had minimal to no mature conifer overstory influence, as well as contained an open overstory (e.g., FB37TD014 and FB37TD015). Both SLSB and SLS sites had stronger regeneration of aspen suckers than CPB and CP sites, where conifer density and basal area remained high. When mean mature conifer density was ≤ 2 trees per hectare, we consistently saw abundant aspen regeneration. Little aspen regeneration was consistently seen when mean mature conifer density was ≥ 16 trees per hectare (Figure 2.7). Future experimental work in these and similar forest types should be conducted to determine a possible threshold where abundant suckering is consistently seen. Due to shading of the overstory and understory, soil temperatures, which affects aspen recruitment, light and nutrient availability, which affect aspen growth, are decreased (Gradowski *et al*., 2010). It has been observed in previous studies that stands with more than 50% conifers had low soil temperatures due to a litter layer consisting of branches in various levels of decomposition and conifer needles (Amacher *et al*., 2001) as well as a result of significant shading from the overstory (Messier *et al*., 1998; Calder *et al*., 2011) thus reducing recruitment potential. Reduction of light in mixed and dominant conifer stands also reduces the likelihood of mycorrhizal infection of aspen roots, further inhibiting nutrient uptake and therefore, limiting aspen regeneration (Clark and St. Clair, 2011).

Aspen responded well to fire disturbance (Bartos and Mueggler, 1981; Brown and DeByle, 1987; Romme *et al*., 1995; Smith *et al*., 2011a; Shinneman *et al*., 2013). In addition to mechanical treatment, two plots were also broadcast burned and produced the strongest aspen sucker response. They were the only two sites that met the objective of 2500 suckers/ha two growing seasons after treatment. More specifically, aspen regeneration was stronger at SLSB sites than at CPB sites. As a result, I suggest that burning alone does not stimulate prolific suckering which agrees with the literature (Smith *et al*., 2011a; Calder and St. Clair, 2012). In another comparison, where shrub and tree cover was high within the understory at one SLS site, there was also low regeneration of aspen. Amacher *et al*. (2001) noted that shading by herbaceous or shrub cover further insulates soil, decreasing soil temperatures during the growing season, thus limiting regeneration of aspen. This could imply that shrub cover may be a threat in aspen stands not burned.

Though browsing of aspen suckers is a concern throughout the Intermountain West (Hessl, 2002; Seager *et al*., 2013), it was not a concern at my sites. Despite the presence of elk and moose pellets found near transects, browsing by wild ungulates on the aspen suckers appeared limited. Other vegetation, such as *Ceanothus* spp., a common shrub species preferred for browsing year-round by wild ungulates (Conard *et al*., 1985; Huffman *et al*., 2009), seemed to be preferred for browsing. This is consistent with results seen by Kay (2001) who noticed that elk preferred to browse on shrubs in an elk winter range within Yellowstone National Park.

Resilience of aspen stands in the Intermountain West is a rising concern in management of aspen stands (Rogers *et al* 2013). Westerling *et al*. (2006) found that an increase in wildfire frequency and severity was not only enhanced by accumulations of fuel over time, but also by increased summer and spring temperatures. There has been an increased occurrence of earlier spring snowmelt, associated with warmer springs. Though the decline of vigor and growth in aspen (Hogg *et al*., 2008); Worrall *et al*., 2013) has been linked to drought conditions, changing disturbance and climate regimes may favor aspen over conifers in seral, co-dominant stands (Kulakowski *et al*., 2013) by promoting wildfires (Westerling *et al*., 2006). Furthermore, changes in temperature and precipitation regimes (Dutzik and Willcox, 2010) are promoting widespread bark beetle outbreaks in conifer stands (Kulakowski *et al*., 2003) throughout western North America, which may favor aspen dominance over conifers (Raffa *et al*., 2008).

MANAGEMENT IMPLICATIONS AND LIMITATIONS

Results from my study suggest that future aspen restoration projects in Soda Springs, ID should undergo substantial mechanical conifer removal such as that seen in the slash/lop and scatter treatment, followed by a broadcast burn in order to promote the strongest aspen sucker response. My results agree with published studies on conifer removal (Collins *et al*., 2011) and the use of prescribed fire (Smith *et al*., 2011a) that have been found to stimulate prolific aspen suckering (Bates *et al*., 2006).

In future quaking aspen monitoring efforts, multiple transects set in cardinal directions from the re-bar, instead of single transects, would increase the statistical significance of the detection of a response of the aspen suckers. This project only had one transect per site. I observed that though there were no suckers found in density belts within certain sites after treatments, there were suckers found in fixed-area plots, indicating that there is some regeneration of aspen elsewhere. A control plot should be established to ensure statistical significance of the treatments. Treatments should be evenly applied at each site and the number of samples (transects) should be increased. Treatments were not evenly applied and the number of transects was too small of a sample to detect a change or difference before and two growing seasons after treatment. Timing of treatments should also be consistent among all sites, in contrast to the sites observed in my study, which were treated at different years. Density belts should be monitored consistently in order to have a balanced and accurate dataset over time. Monitoring should be conducted on sites that were burned in the fall, to observe the response of overstory, understory vegetation, in addition to aspen regeneration. Measuring of fuels should be conducted after burns to determine the effectiveness of reducing fuel loads and conifer density.

The results from this study are empirical and of limited scope. However, these transects should continue to be monitored in order to observe the long-term effects of silvicultural treatments on overstory and understory vegetation, which may be heavily influenced by climate variability.

Table 2.1. Soda Springs, ID, site treatment dates, monitoring dates, and monitoring protocols.

SITE	TREATMENT	TREATMENT YEARS: *MECHANICAL TREATMENT*	TREATMENT YEARS: *BURN TREATMENT*	DATA MONITORED
FB37_Aspen_013	Slash/Lop and Scatter	2010	--	Aspen Regeneration, Understory
FB37_Aspen_015	Slash/Lop and Scatter	2010	--	Aspen Regeneration, Understory
FB37029	Slash/Lop and Scatter	2011	--	Aspen Regeneration, Overstory, Understory
FB37030	Slash/Lop and Scatter	2011	--	Aspen Regeneration, Overstory, Understory
FB37TD014	Slash/Lop and Scatter with Broadcast Burn	2008	2009	Aspen Regeneration, Overstory
FB37TD015	Slash/Lop and Scatter with Broadcast Burn	2008	2009	Aspen Regeneration, Overstory
FB37TD016	Cut and Pile with Broadcast Burn	2008	2009	Aspen Regeneration, Overstory
FB37TD017	Cut and Pile with Broadcast Burn	2008	2009	Aspen Regeneration, Overstory
FB37TD018	Cut and Pile	2008	--	Aspen Regeneration, Overstory

Table 2.2. Parameters used to simulate low fire behavior conditions in the 2009 spring broadcast burn in Soda Springs, ID, in BehavePlus version 3.0.2 (2005).

Category	**Variable**	**Unit of Measure**	**Value**
Fuel/Vegetation, Surface/Understory	Fuel Model	--	11 Light Logging Slash (S)
Fuel/Vegetation, Overstory	Tree Height	m	7.6
	Crown Ratio	--	0.6
	Mortality Tree Species	--	PSEMEN Pseudotsuga menziesii (Douglas-fir)
	Bark Thickness	cm	4.1
Fuel Moisture	1-h Moisture	%	8, 10, 12, 14, 16
	10-h Moisture	%	18
	100-h Moisture	%	20
	Live Herbaceous Moisture	%	--
	Live Woody Moisture	%	--
Weather	Midflame Wind Speed (upslope)	km/h	3, 6, 10, 13, 16
	Air Temperature	°F	60
	Fuel Shading from the Sun	%	30
Terrain	Slope Steepness	%	20
Acceptable Fire Conditions	Surface Rate of Spread (max)	m/h	0 - 1448
	Flame Length	m	0 - 2.4
	Scorch Height	m	0
	Probability of Mortality	%	0
	Probability of Ignition from a Firebrand	%	0 - 60
Output Variables	Surface Rate of Spread (max) (m/h) [SURFACE] Flame Length (m) [SURFACE] Scorch Height (m) [SCORCH] Probability of Mortality (%) [MORTALITY] Probability of Ignition from a Firebrand (%) [IGNITE]		
Modules	SURFACE, SCORCH, MORTALITY, IGNITE		

Table 2.3. Simulated low fire behavior conditions for the 2009 spring broadcast prescribed burn in Soda Springs, ID, using BehavePlus version 3.0.2 (2005).

Surface Rate of Spread (maximum) (m/h)

1-h Moisture	Midflame Wind Speed (upslope) km/h				
%	*3*	*6*	*10*	*13*	*16*
8	48.28	86.50	126.74	170.99	217.26
10	36.21	66.39	98.57	132.77	168.98
12	22.13	38.22	58.34	76.44	98.57
14	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00

Flame Length (m)

1-h Moisture	Midflame Wind Speed (upslope) km/h				
%	*3*	*6*	*10*	*13*	*16*
8	0.64	0.85	1.01	1.16	1.31
10	0.52	0.70	0.82	0.94	1.07
12	0.34	0.43	0.52	0.58	0.67
14	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00

Scorch Height (m)

1-h Moisture	Midflame Wind Speed (upslope) km/h				
%	*3*	*6*	*10*	*13*	*16*
8	2.13	2.13	2.13	2.13	2.13
10	1.52	1.52	1.52	1.22	1.22
12	0.61	0.61	0.30	0.30	0.30
14	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00

Probability of Mortality (%)

1-h Moisture	Midflame Wind Speed (upslope) km/h				
%	*3*	*6*	*10*	*13*	*16*
8	4	4	4	4	4
10	4	4	4	4	4
12	4	4	4	4	4
14	4	4	4	4	4
16	4	4	4	4	4

Probability of Ignition from a Firebrand (%)

1-h Moisture	Midflame Wind Speed (upslope) km/h				
%	*3*	*6*	*10*	*13*	*16*
8	38	38	38	38	38
10	28	28	28	28	28
12	21	21	21	21	21
14	15	15	15	15	15
16	10	10	10	10	10

Table 2.4. Mature tree densities and basal areas monitored before and up to four growing seasons after treatment, in slash/lop and scatter with broadcast burn and cut and pile with broadcast burn treated sites, in comparison with aspen regeneration within these sites in Soda Springs, ID.

				MATURE TREES							
				DOUGLAS-FIR		ROCKY MOUNTAIN JUNIPER		QUAKING ASPEN		BIGTOOTH MAPLE	
MONITORING STATUS	SITE	TREATMENT	ASPEN REGENERATION (suckers/ha)	TPH	BA (m^2/ha)	TPH	BA (m^2/ha)	TPH	BA (m^2/ha)	TPH	BA (m^2/ha)
PRETREATMENT	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	264	68.80	9.00	0.00	0.00	48.56	7.36	0.00	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	588	20.23	1.46	4.05	3.21	16.19	2.50	0.00	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	323	68.80	33.52	0.00	0.00	0.00	0.00	0.00	0.00
	FB37TD017	Cut and Pile with Broadcast Burn	294	40.47	39.38	0.00	0.00	4.05	0.56	0.00	0.00
GROWING SEASON 1	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	14573	0.00	0.00	0.00	0.00	48.56	8.72	0.00	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	28469	4.05	2.02	0.00	0.00	4.05	0.28	0.00	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	1424	32.37	26.22	0.00	0.00	0.00	0.00	0.00	0.00
	FB37TD017	Cut and Pile with Broadcast Burn	511	36.42	39.54	0.00	0.00	4.05	0.58	0.00	0.00
GROWING SEASON 2	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	8726	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	14338	4.05	2.18	0.00	0.00	8.09	0.44	0.00	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	88	32.37	26.03	0.00	0.00	0.00	0.00	0.00	0.00
	FB37TD017	Cut and Pile with Broadcast Burn	0	36.42	40.04	0.00	0.00	0.00	0.00	0.00	0.00
GROWING SEASON 3	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	5993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	15043	4.05	2.38	0.00	0.00	16.19	0.99	0.00	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	--	--	--	--	--	--	--	--	--
	FB37TD017	Cut and Pile with Broadcast Burn	0	32.37	35.74	0.00	0.00	0.00	0.00	0.00	0.00
GROWING SEASON 4	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	1792	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	4701	0.01	0.01	0.00	0.00	0.02	0.00	0.00	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	30	0	0	0	0	0	0	0	0
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.5. Sapling densities monitored before and up to four growing seasons after treatment, in slash/lop and scatter with broadcast burn and cut and pile with broadcast burn treated sites, in comparison with aspen regeneration within these sites in Soda Springs, ID.

				SAPLINGS PER HECTARE			
MONITORING STATUS	**SITE**	**TREATMENT**	**ASPEN REGENERATION (suckers/ha)**	**DOUGLAS-FIR**	**ROCKY MOUNTAIN JUNIPER**	**QUAKING ASPEN**	**BIGTOOTH MAPLE**
PRETREATMENT	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	264	368.26	12.14	60.70	48.56
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	588	331.84	12.14	611.08	89.03
	FB37TD016	Cut and Pile with Broadcast Burn	323	8.09	0.00	101.17	109.27
	FB37TD017	Cut and Pile with Broadcast Burn	294	8.09	0.00	32.37	36.42
GROWING SEASON 1	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	14573	0.00	0.00	28.33	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	28469	4.05	4.05	388.50	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	1424	0.00	0.00	28.33	24.28
	FB37TD017	Cut and Pile with Broadcast Burn	511	0.00	0.00	52.61	20.23
GROWING SEASON 2	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	8726	0.00	0.00	68.80	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	14338	24.28	4.05	234.72	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	88	0.00	0.00	56.66	36.42
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.00	0.00	64.75	16.19
GROWING SEASON 3	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	5993	0.00	0.00	226.62	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	15043	4.05	4.05	311.61	68.80
	FB37TD016	Cut and Pile with Broadcast Burn	--	--	--	--	--
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.00	0.00	101.17	28.33
GROWING SEASON 4	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	1792	0.00	0.00	6.07	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	4701	0.04	0.00	10.89	0.73
	FB37TD016	Cut and Pile with Broadcast Burn	30	0	0	0	0
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.00	0.00	0.49	0.04

Table 2.6. Seedling densities monitored before and up to four growing seasons after treatment, in slash/lop and scatter with broadcast burn and cut and pile with broadcast burn treated sites, in comparison with aspen regeneration within these sites in Soda Springs, ID.

MONITORING STATUS	SITE	TREATMENT	ASPEN REGENERATION (suckers/ha)	SEEDLINGS PER HECTARE			
				DOUGLAS-FIR	ROCKY MOUNTAIN JUNIPER	QUAKING ASPEN	BIGTOOTH MAPLE
PRETREATMENT	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	264	0.00	0.00	0.00	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	588	0.00	40.47	40.47	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	323	0.00	0.00	80.94	161.87
	FB37TD017	Cut and Pile with Broadcast Burn	294	0.00	0.00	0.00	364.22
GROWING SEASON 1	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	14573	0.00	0.00	7405.75	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	28469	0.00	40.47	526.09	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	1424	0.00	0.00	121.41	80.94
	FB37TD017	Cut and Pile with Broadcast Burn	511	0.00	0.00	0.00	242.81
GROWING SEASON 2	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	8726	0.00	0.00	11776.36	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	14338	0.00	0.00	1254.53	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	88	0.00	0.00	121.41	40.47
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.00	0.00	40.47	242.81
GROWING SEASON 3	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	5993	0.00	0.00	2630.46	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	15043	40.47	80.94	1214.06	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	--	--	--	--	--
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.00	0.00	161.87	202.34
GROWING SEASON 4	FB37TD014	Slash/Lop and Scatter with Broadcast Burn	1792	0.00	0.00	1.21	0.00
	FB37TD015	Slash/Lop and Scatter with Broadcast Burn	4701	0.00	0.00	0.49	0.00
	FB37TD016	Cut and Pile with Broadcast Burn	30	0	0	0	0
	FB37TD017	Cut and Pile with Broadcast Burn	0	0.00	0.00	0.00	0.20

Table 2.7. Mature tree densities and basal areas monitored before and two growing seasons after treatment, in slash/lop and scatter without broadcast burn and cut and pile without broadcast burn treated sites, in comparison with aspen regeneration within these sites in Soda Springs, ID.

				MATURE TREES							
				DOUGLAS-FIR		**ROCKY MOUNTAIN JUNIPER**		**QUAKING ASPEN**		**BIGTOOTH MAPLE**	
MONITORING STATUS	**SITE**	**TREATMENT**	**ASPEN REGENERATION (suckers/ha)**	**TPH**	**BA (m²/ha)**	**TPH**	**BA (m²/ha)**	**TPH**	**BA (m²/ha)**	**TPH**	**BA (m²/ha)**
PRETREATMENT	FB37029	Slash/Lop and Scatter	646	8.09	0.66	0.00	0.00	36.42	5.16	24.28	1.51
	FB37030	Slash/Lop and Scatter	999	4.05	0.30	24.28	6.92	12.14	2.04	0.00	0.00
	FB37TD018	Cut and Pile	323	56.66	33.04	0.00	0.00	8.09	19.81	0.00	0.00
GROWING SEASON 2	FB37029	Slash/Lop and Scatter	793	0.00	0.00	0.00	0.00	0.09	0.01	0.08	0.00
	FB37030	Slash/Lop and Scatter	1117	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00
	FB37TD018	Cut and Pile	0	36.42	47.71	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.8. Sapling densities monitored before and two growing seasons after treatment, in slash/lop and scatter without broadcast burn and cut and pile without broadcast burn treated sites, in comparison with aspen regeneration within these sites in Soda Springs, ID.

				SAPLINGS PER HECTARE			
MONITORING STATUS	**SITE**	**TREATMENT**	**ASPEN REGENERATION (suckers/ha)**	**DOUGLAS-FIR**	**ROCKY MOUNTAIN JUNIPER**	**QUAKING ASPEN**	**BIGTOOTH MAPLE**
PRETREATMENT	FB37029	Slash/Lop and Scatter	646	125.45	0.00	113.31	234.72
	FB37030	Slash/Lop and Scatter	999	28.33	16.19	186.16	0.00
	FB37TD018	Cut and Pile	323	24.28	0.00	8.09	105.22
GROWING SEASON 2	FB37029	Slash/Lop and Scatter	793	0.00	0.00	0.40	0.81
	FB37030	Slash/Lop and Scatter	1117	0.00	0.00	0.32	0.00
	FB37TD018	Cut and Pile	0	12.14	0.00	24.28	68.80

Table 2.9. Seedling densities monitored before and two growing seasons after treatment, in slash/lop and scatter without broadcast burn and cut and pile without broadcast burn treated sites, in comparison with aspen regeneration within these sites in Soda Springs, ID.

				SEEDLINGS PER HECTARE			
MONITORING STATUS	**SITE**	**TREATMENT**	**ASPEN REGENERATION (suckers/ha)**	**DOUGLAS-FIR**	**ROCKY MOUNTAIN JUNIPER**	**QUAKING ASPEN**	**BIGTOOTH MAPLE**
PRETREATMENT	FB37029	Slash/Lop and Scatter	646	161.87	0.00	0.00	404.69
	FB37030	Slash/Lop and Scatter	999	0.00	0.00	40.47	0.00
	FB37TD018	Cut and Pile	323	0.00	0.00	0.00	0.00
GROWING SEASON 2	FB37029	Slash/Lop and Scatter	793	0.04	0.00	0.53	0.97
	FB37030	Slash/Lop and Scatter	1117	0.00	0.08	0.20	0.00
	FB37TD018	Cut and Pile	0	0.00	0.00	0.00	0.00

Table 2.10. Mean aspen regeneration (suckers/ha) in sites that were not burned (thin-only) in comparison to mean aspen regeneration in sites that were burned (thin-plus-burn) in Soda Springs, ID.

	MEAN ASPEN REGENERATION (suckers/ha)		
MONITORING STATUS	**THIN ONLY**	**THIN PLUS BURN**	**N (THIN ONLY, THIN PLUS BURN)**
PRETREATMENT	564	367	(5, 4)
GROWING SEASON 1	81	11244	(1, 4)
GROWING SEASON 2	576	5788	(5, 4)
GROWING SEASON 3	0	7012	(1, 3)
GROWING SEASON 4	0	1631	(1, 4)

Table 2.11. Understory mean percent cover categorized by lifeform, with aspen regeneration before and two growing seasons after treatment in four sites that received the slash/lop and scatter treatment in Soda Springs, ID.

MONITORING STATUS	SITE	TREATMENT	ASPEN REGENERATION (SUCKERS/HA)	LIFEFORM				
				TREES	SHRUBS	FORBHERB	GRASSES	LITTER
PRETREATMENT	FB37_Aspen_013	Slash/Lop and Scatter	470	52.00	34.67	8.44	28.00	86
	FB37_Aspen_015	Slash/Lop and Scatter	382	27.00	15.67	5.33	10.00	76
	FB37029	Slash/Lop and Scatter	646	12.00	2.00	8.40	4.00	100
	FB37030	Slash/Lop and Scatter	999	4.00	8.00	5.11	22.00	94
GROWING SEASON 2	FB37_Aspen_013	Slash/Lop and Scatter	411	10.00	16.00	5.80	24.00	98
	FB37_Aspen_015	Slash/Lop and Scatter	558	2.00	9.67	8.50	20.67	96
	FB37029	Slash/Lop and Scatter	793	9.00	3.33	7.33	32.00	100
	FB37030	Slash/Lop and Scatter	1117	4.00	11.33	8.00	26.00	98

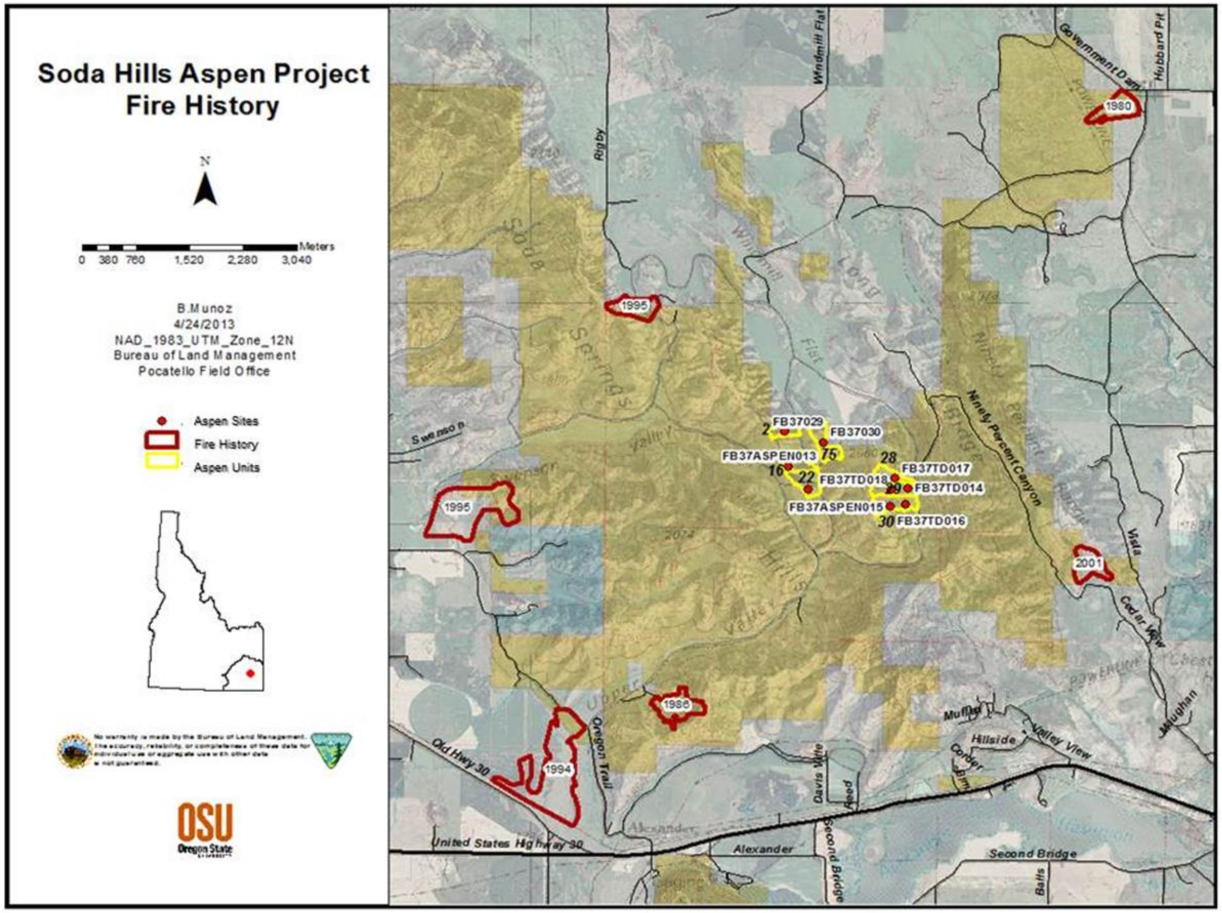

Figure 2.1. Map of recorded fire history near the Soda Springs, ID aspen units and sites.

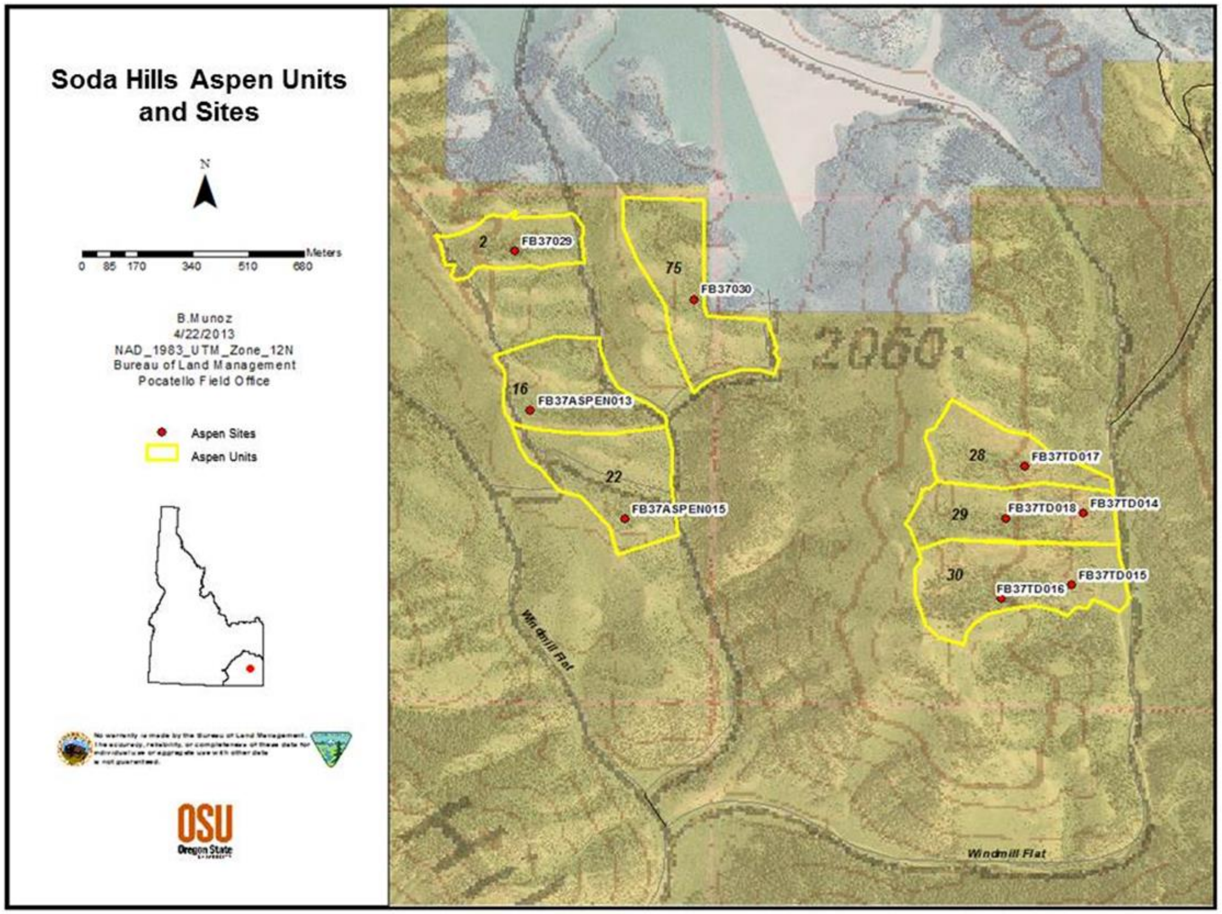

Figure 2.2. Map of Soda Springs, ID aspen units and sites.

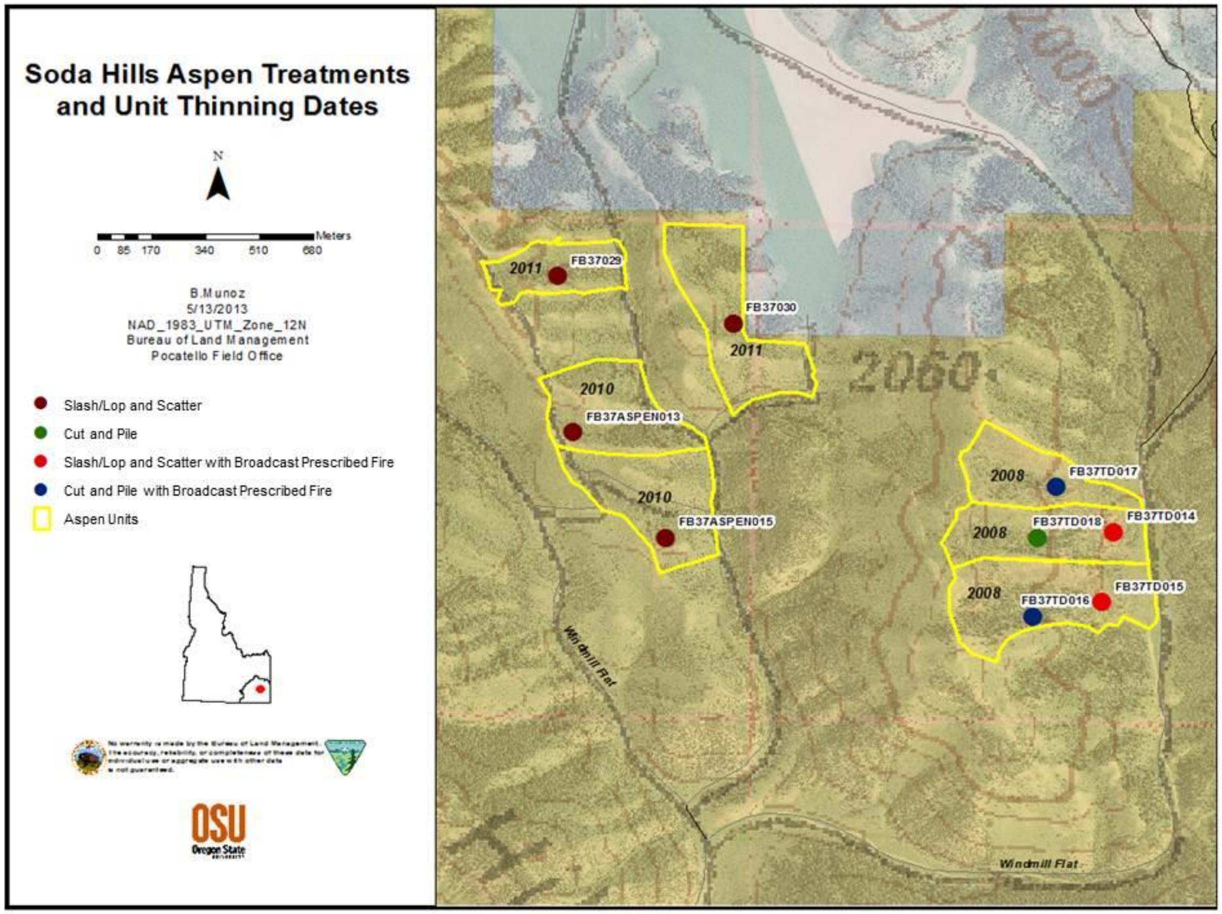

Figure 2.3. Map of treatment distributions aspen units and sites in Soda Springs, ID.

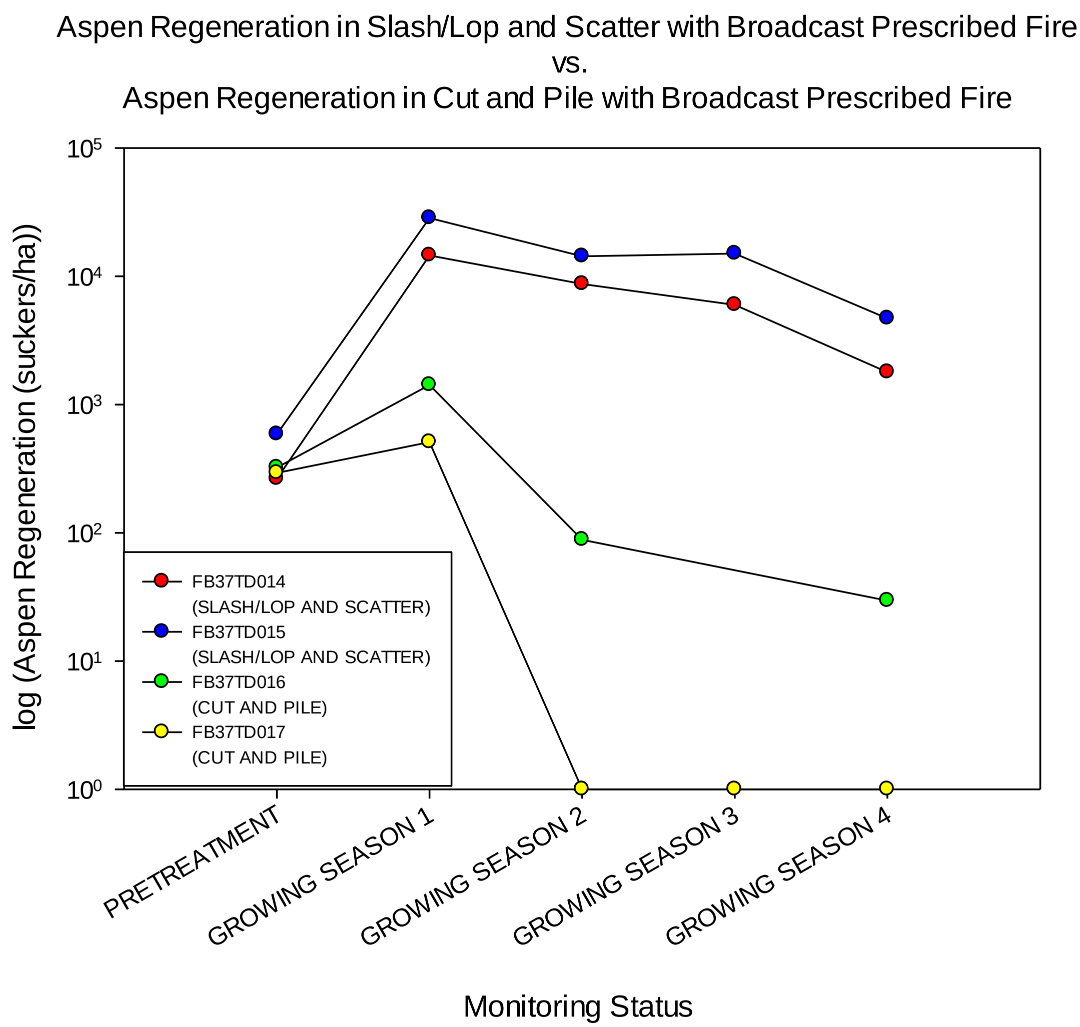

Figure 2.4. Aspen regeneration trends based on logarithmic scale, in slash/lop and scatter plots followed by broadcast burn, in comparison of aspen regeneration trends in cut and pile followed by broadcast burn, before and up to four growing seasons after treatment.

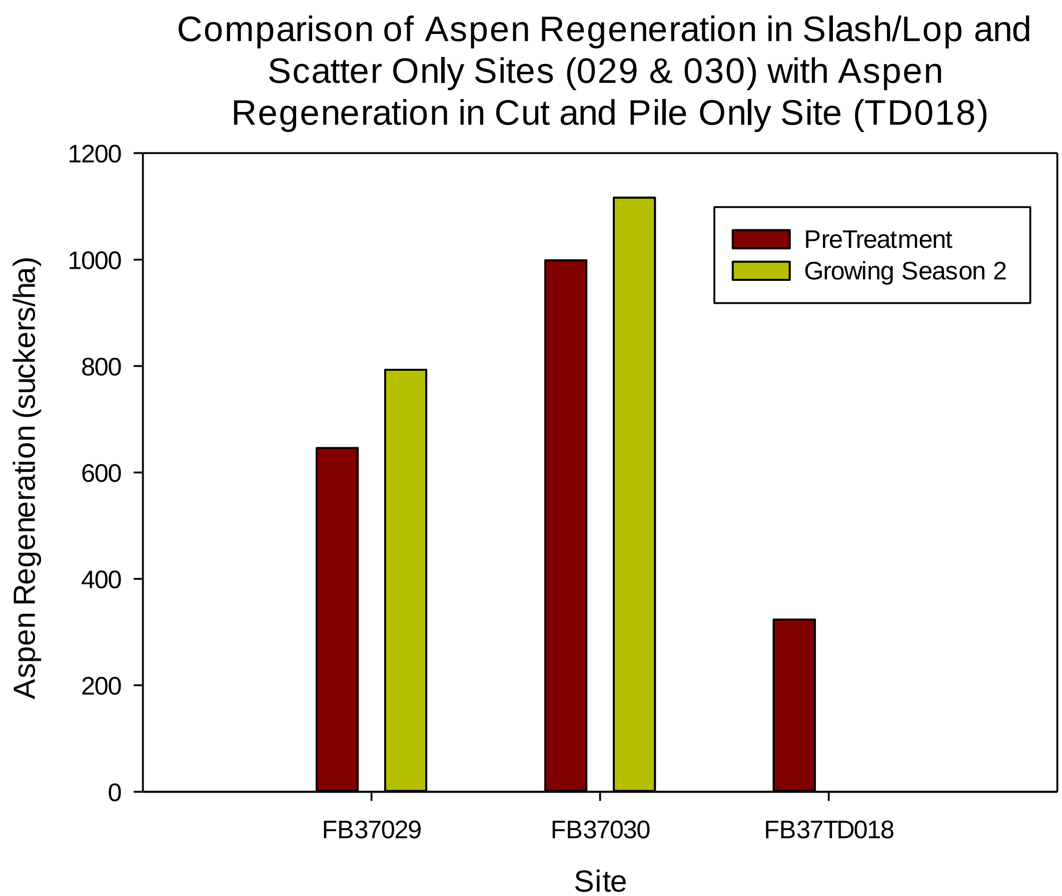

Figure 2.5. Aspen regeneration trends in slash/lop and scatter plots without broadcast burn, in comparison of aspen regeneration trends in cut and pile without broadcast burn, before and two growing seasons after treatment.

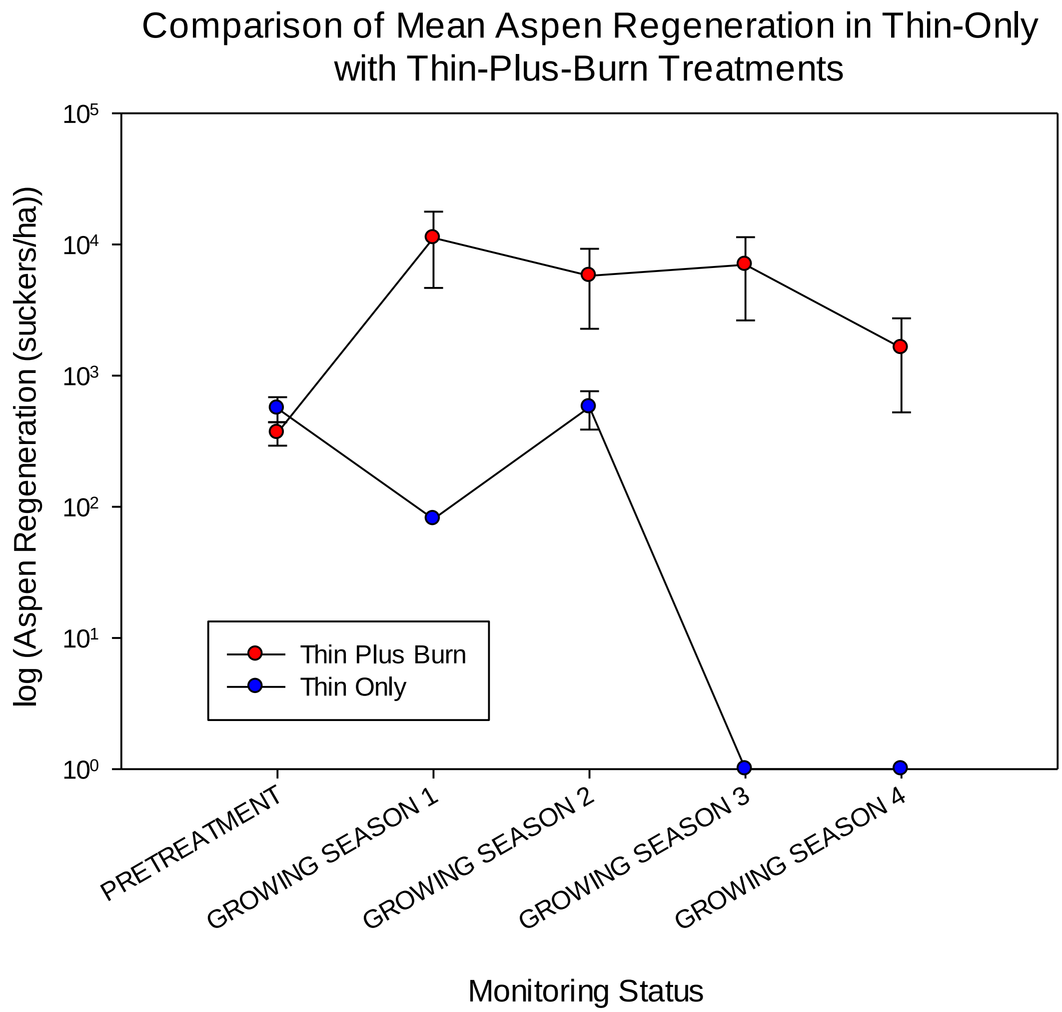

Figure 2.6. Aspen regeneration trends based on logarithmic scale, in thin-plus-burn treatments, in comparison of aspen regeneration trends in thin-only treatments, before and up to four growing seasons after treatment.

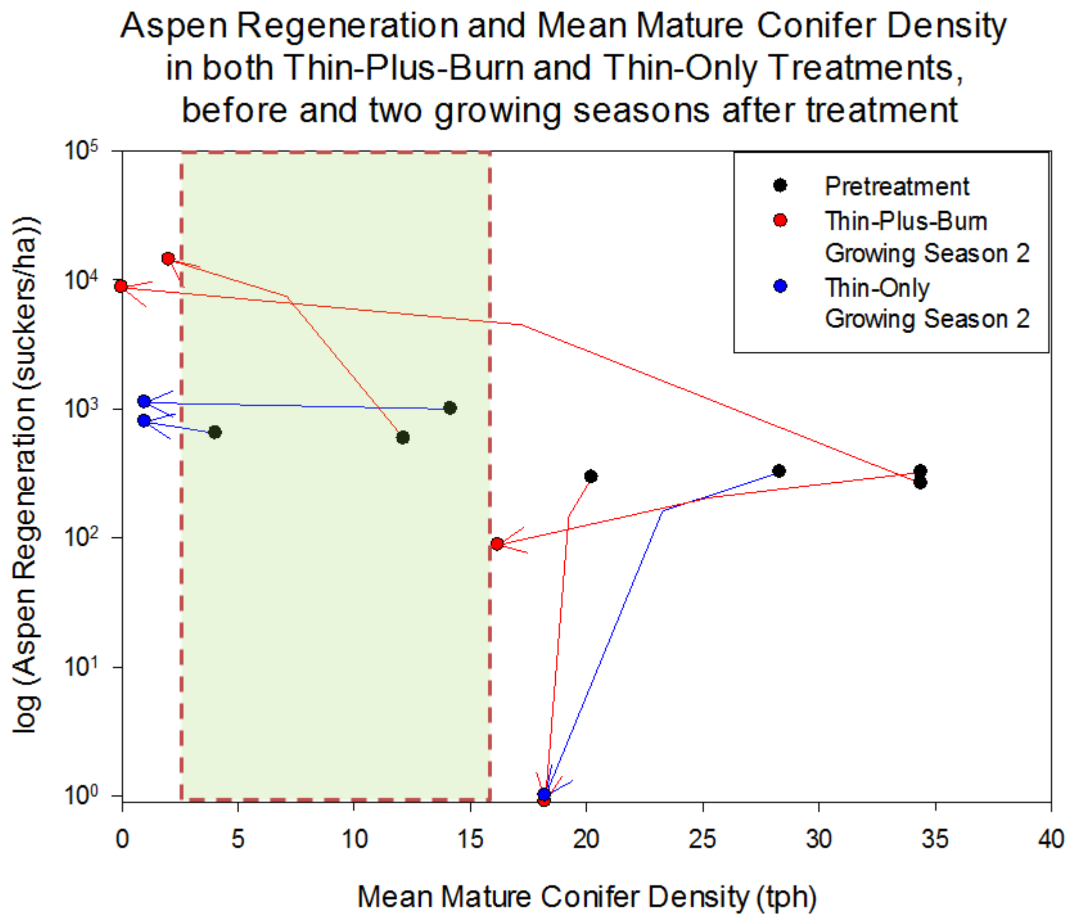

Figure 2.7. Aspen regeneration (logarithmic scale) and mean residual mature conifer density of both Douglas-fir and Rocky Mountain juniper density (linear scale) before and two growing seasons after treatment, in both thin-plus-burn and thin-only treatments, regardless of prior mechanical treatment. Arrows connect stands pre- and post-treatment. The dashed box encompasses the zone within which a potential threshold for abundant aspen regeneration exists. Suckering was consistently seen when mean mature conifer density was ≤ 2 trees per hectare, and little aspen regeneration was consistently seen when mean mature conifer density was ≥ 16 trees per hectare.

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APPENDICES

APPENDIX A. Site Characteristics

Table A.1. Soda Springs, ID sites, coordinates, elevation, and transect azimuths.

SITE	UNIT	UTM ZONE	EASTING	NORTHING	ELEVATION (M)	TRANSECT AZIMUTH
FB37_Aspen_013	16	12 N	443613	4727782	1958	20
FB37_Aspen_015	22	12 N	443898	4727435	1927	0
FB37029	2	12 N	443562	4728286	1981	90
FB37030	75	12 N	444115	4728132	1950	160
FB37TD014	29	12 N	445311	4727456	1946	90
FB37TD015	30	12 N	445277	4727229	1956	90
FB37TD016	30	12 N	445061	4727181	2014	90
FB37TD017	28	12 N	445132	4727606	1989	90
FB37TD018	29	12 N	445075	4727442	2017	90

*All coordinates were recorded under NAD 83 Datum

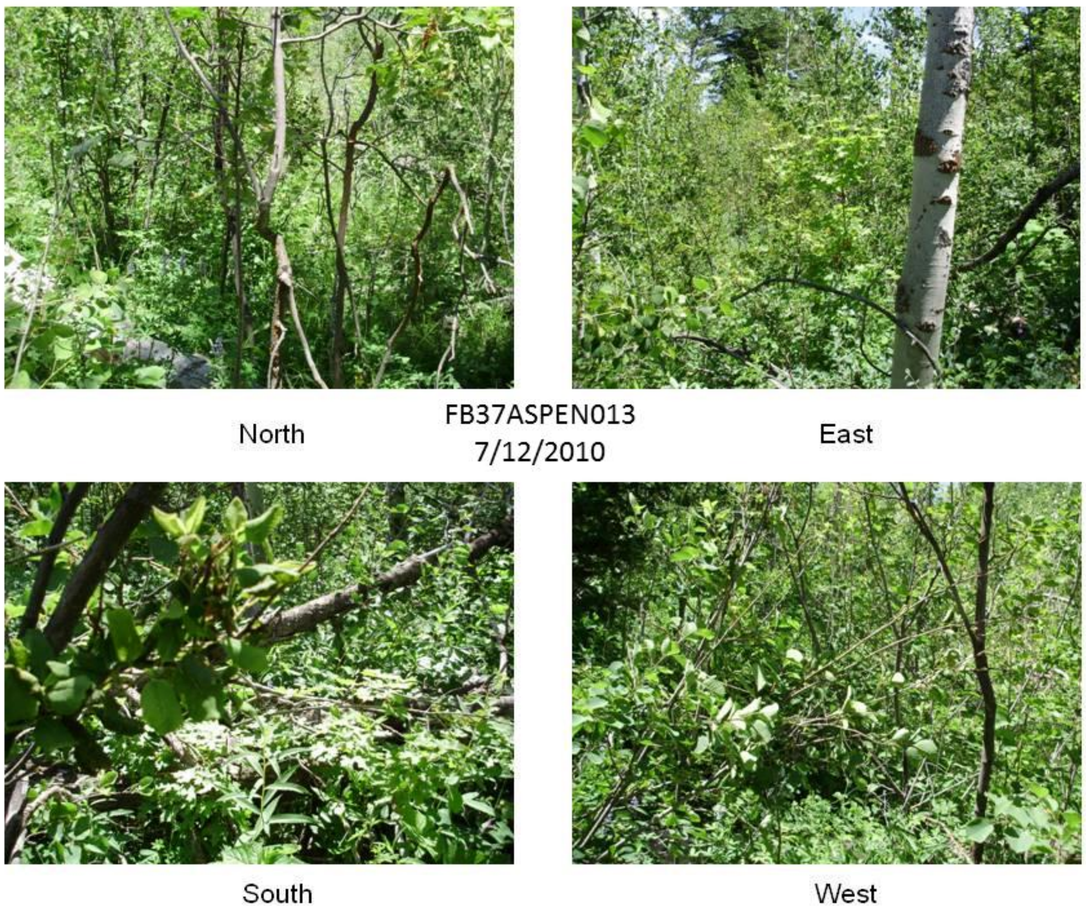


Figure A.1. Site FB37_Aspen_013 in 2010, prior to receiving slash/lop and scatter treatment the same year.

Figure A.2. Site FB37_Aspen_013 in 2012, two growing seasons after receiving slash/lop and scatter treatment in 2010.

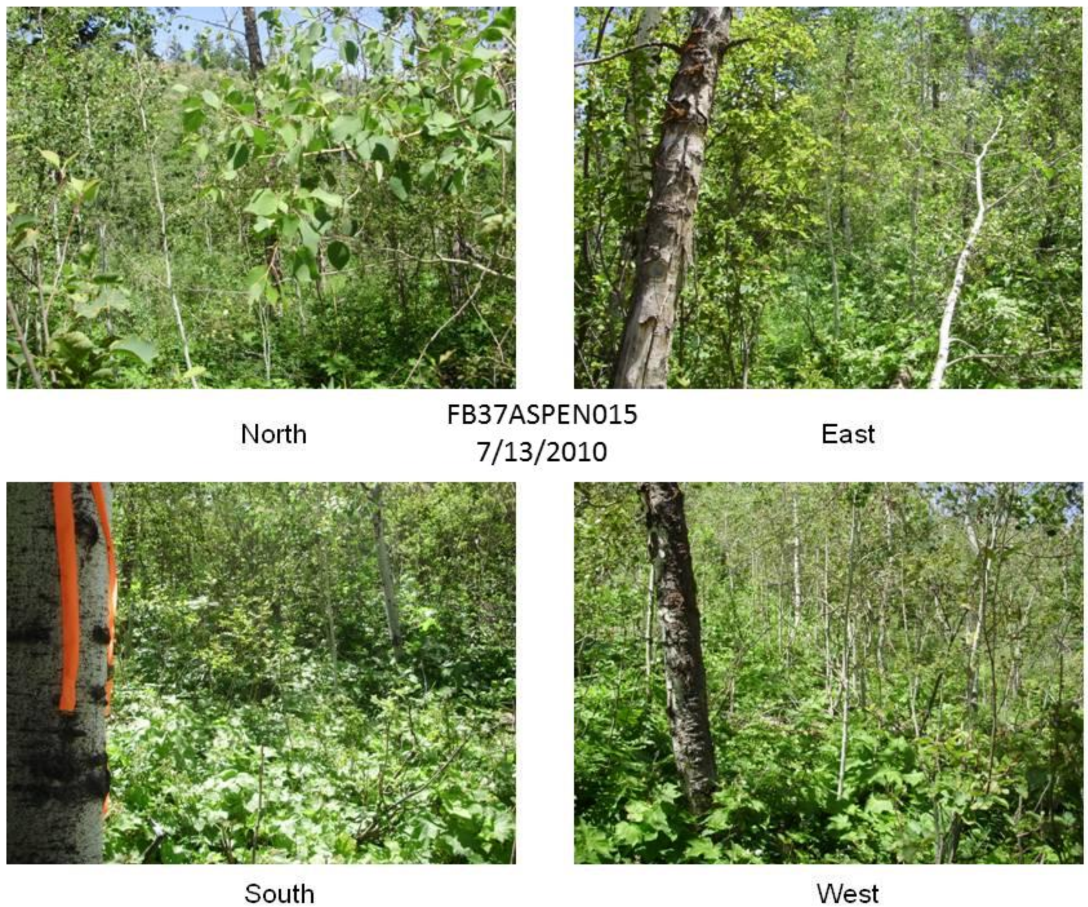


Figure A.3. Site FB37_Aspen_015 in 2010, prior to receiving slash/lop and scatter treatment the same year.

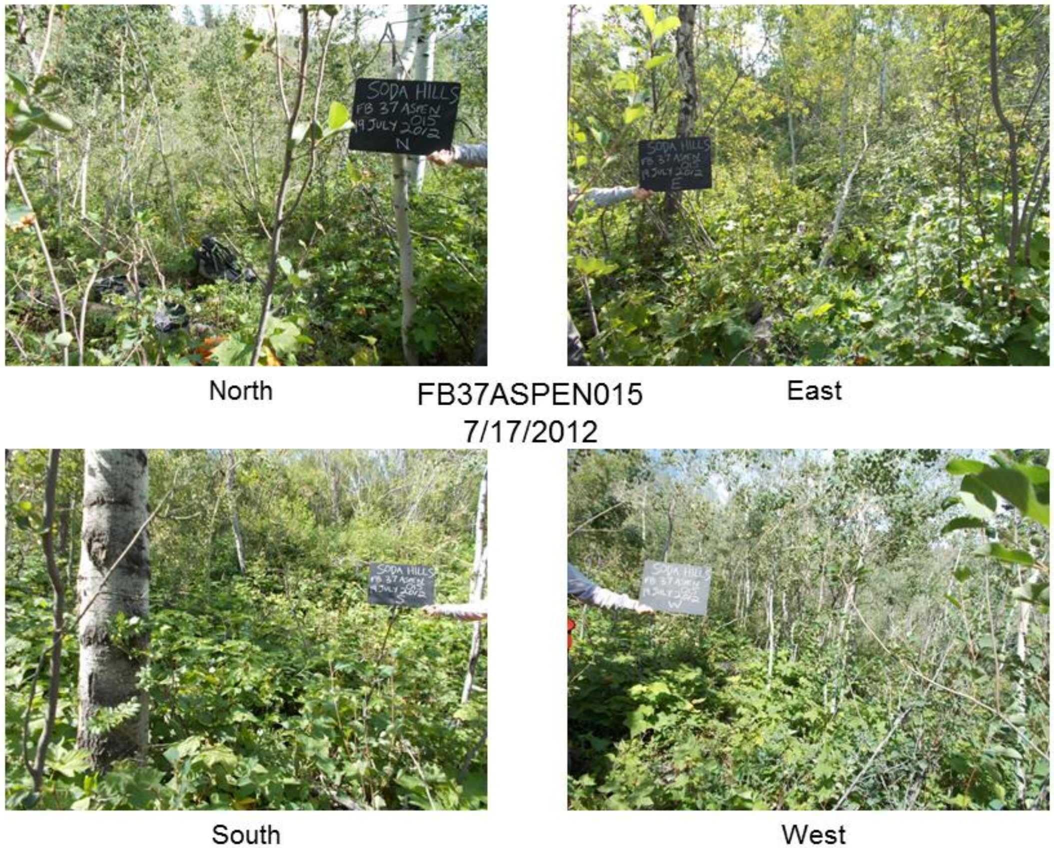


Figure A.4. Site FB37_Aspen_015 in 2012, two growing seasons after receiving slash/lop and scatter treatment in 2010.

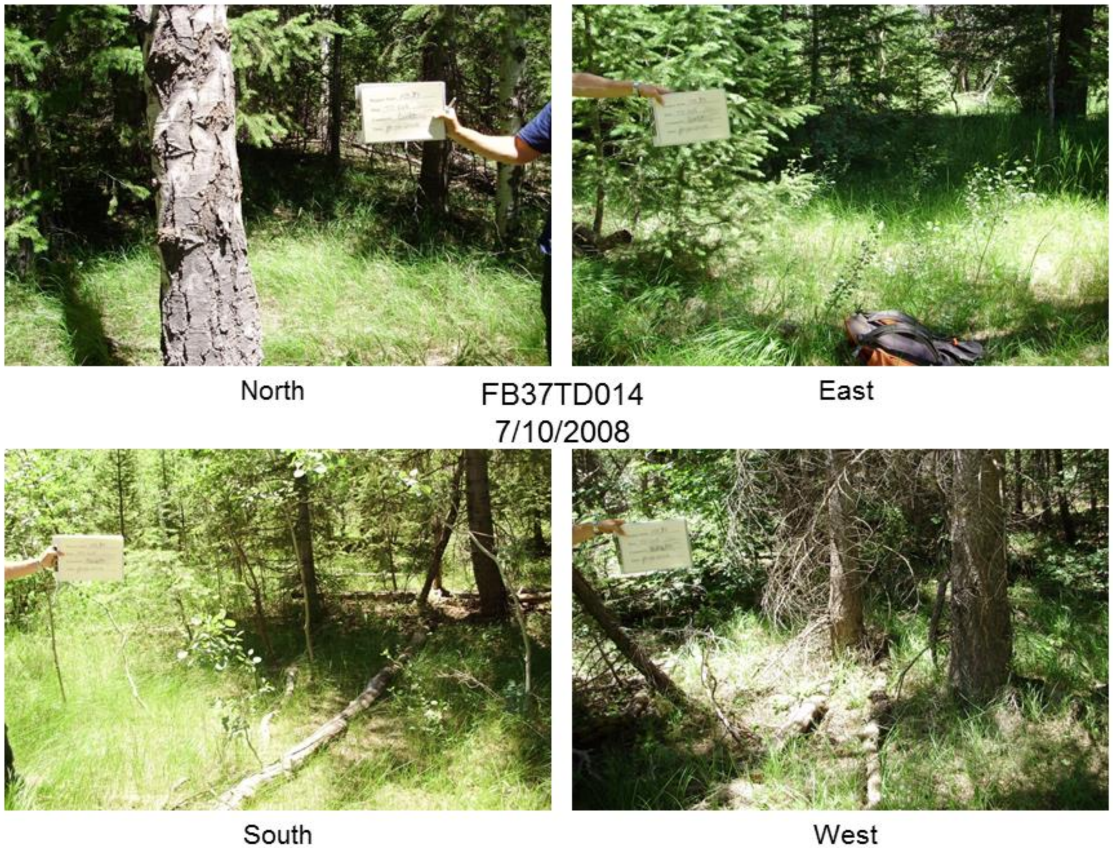


Figure A.5. Site FB37TD014 in 2008, prior to receiving slash/lop and scatter treatment treatment the same year and broadcast burn in 2009.

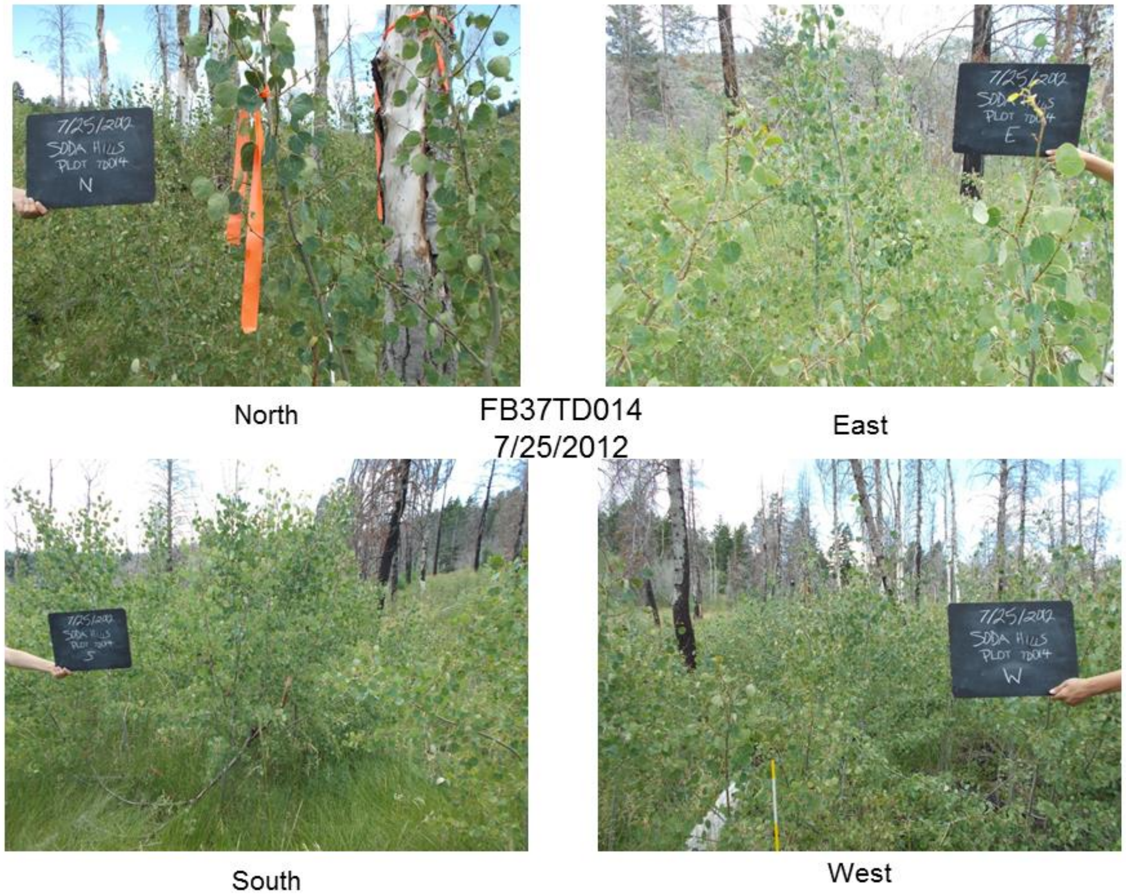


Figure A.6. Site FB37TD014 in 2012, four growing seasons after receiving slash/lop and scatter treatment in 2008 and broadcast burn in 2009.

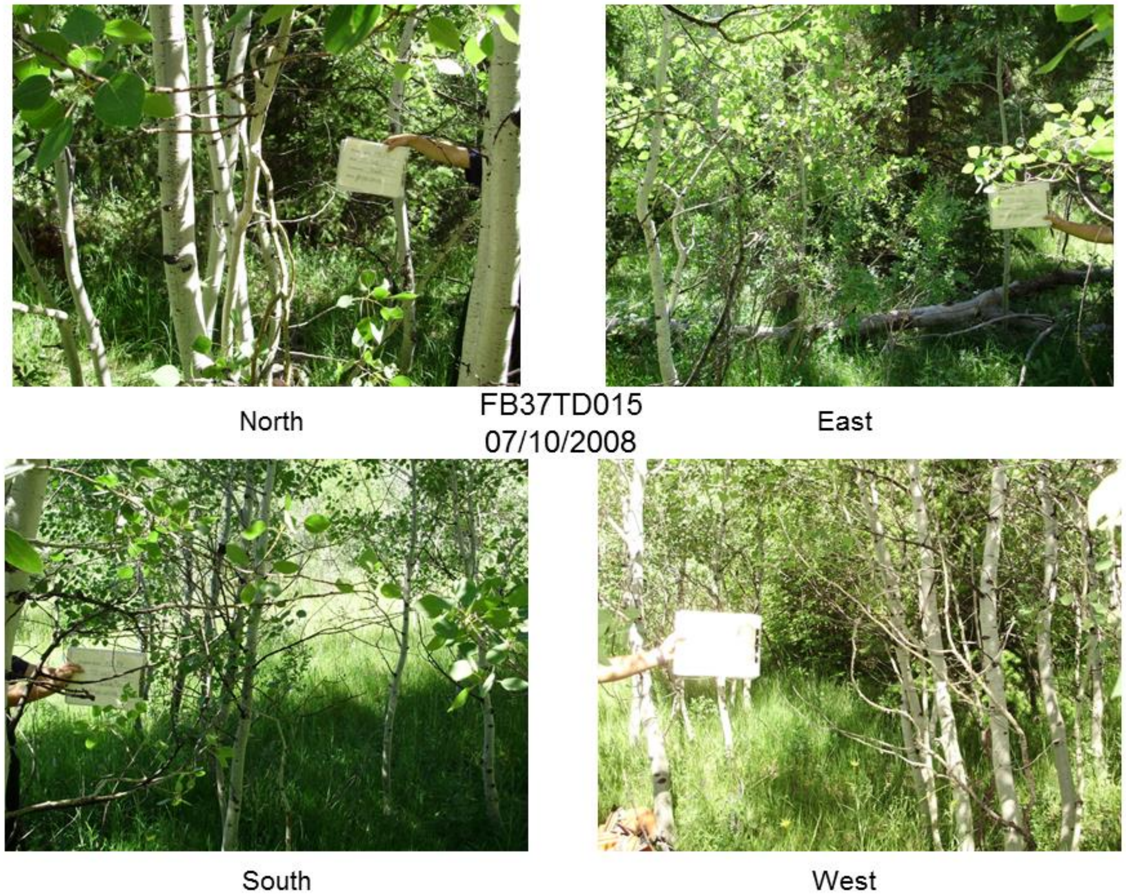
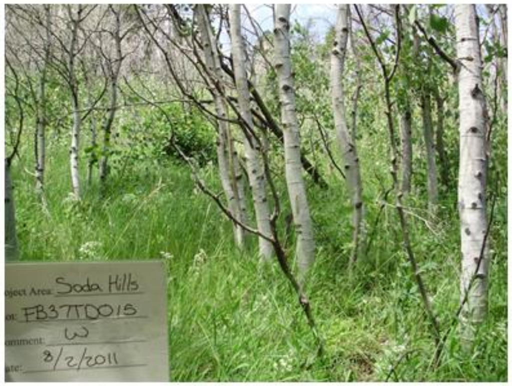


Figure A.7. Site FB37TD015 in 2008, prior to receiving slash/lop and scatter treatment the same year and broadcast burn in 2009.

North

FB37TD015
8/2/2011

East



South

West

Figure A.8. Site FB37TD015 in 2011, three growing seasons after receiving slash/lop and scatter treatment in 2008 and broadcast burn in 2009 (Inserted for clarity on conditions after treatment in comparison to photos taken in 2012).

Figure A.9. Site FB37TD015 in 2012, four growing seasons after receiving slash/lop and scatter treatment in 2008 and broadcast burn in 2009.

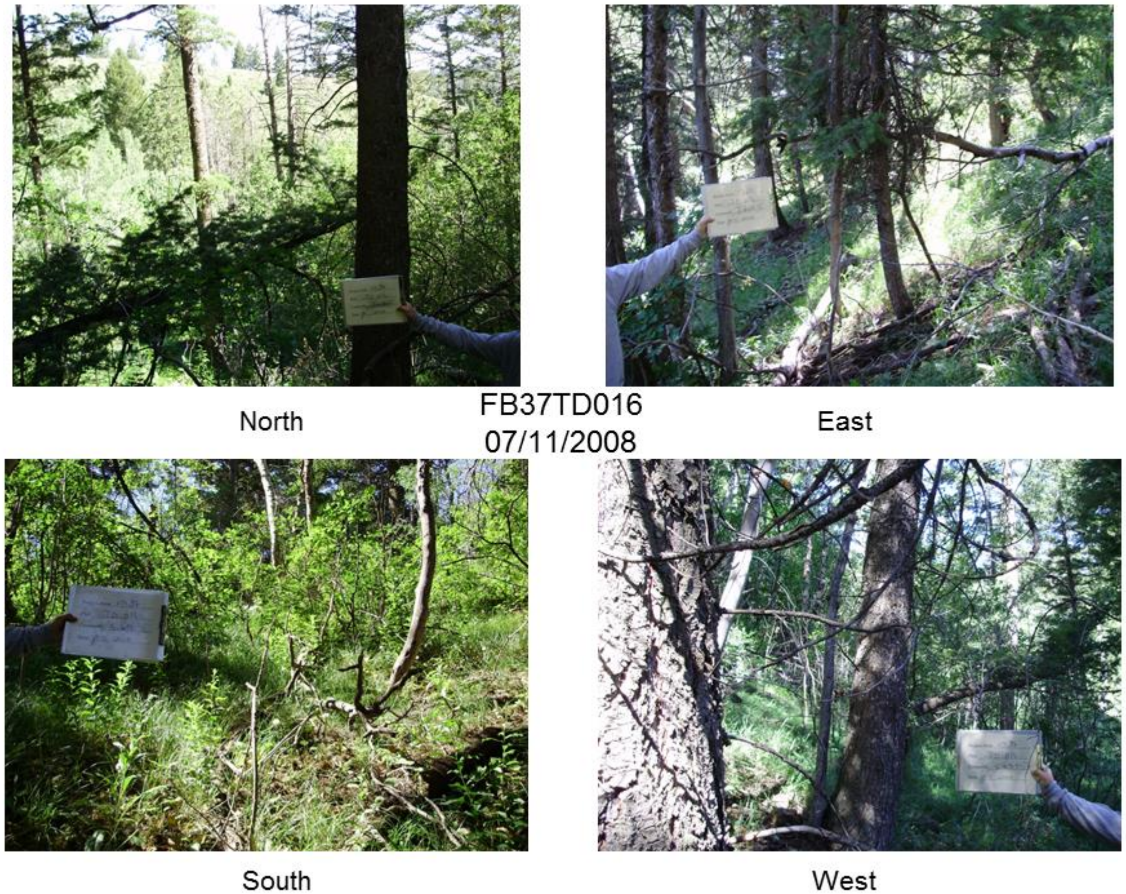


Figure A.10. Site FB37TD016 in 2008, prior to receiving cut and pile treatment the same year and broadcast burn in 2009.

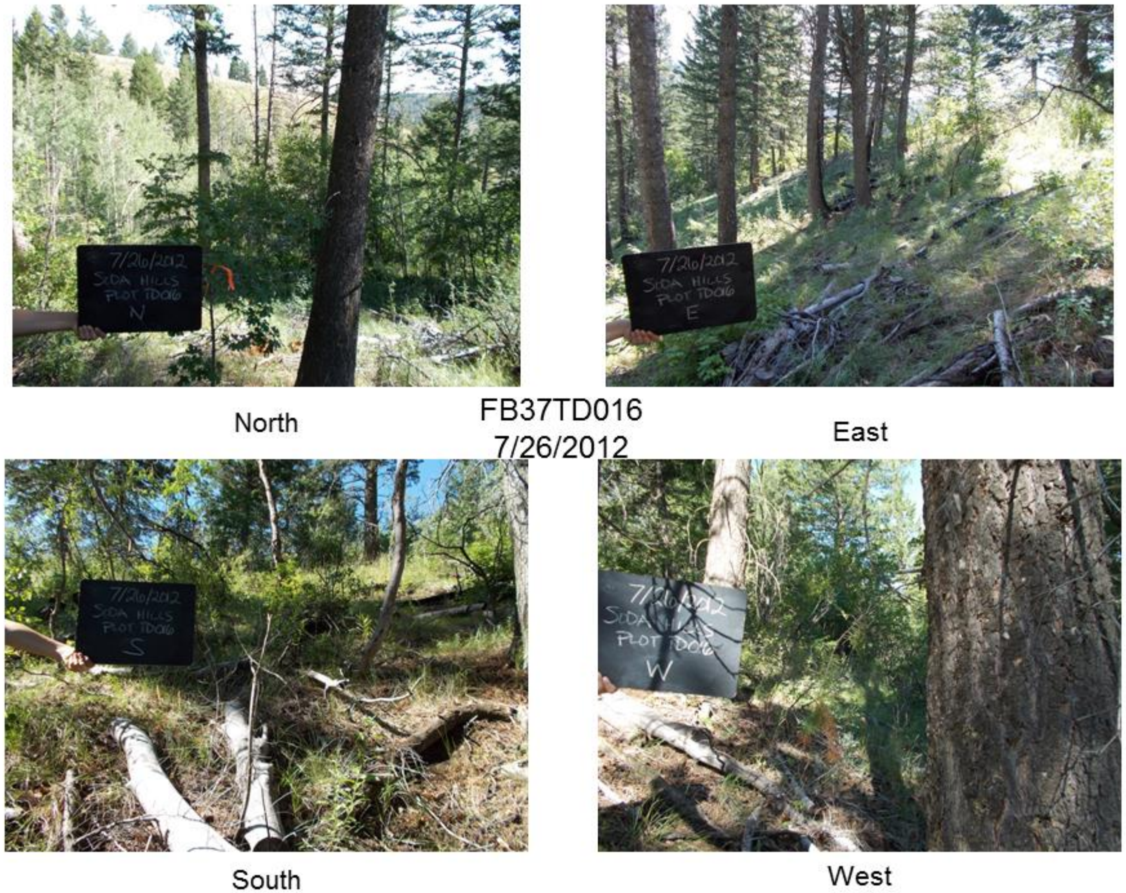


Figure A.11. Site FB37TD016 in 2012, four growing seasons after receiving cut and pile treatment in 2008 and broadcast burn in 2009.

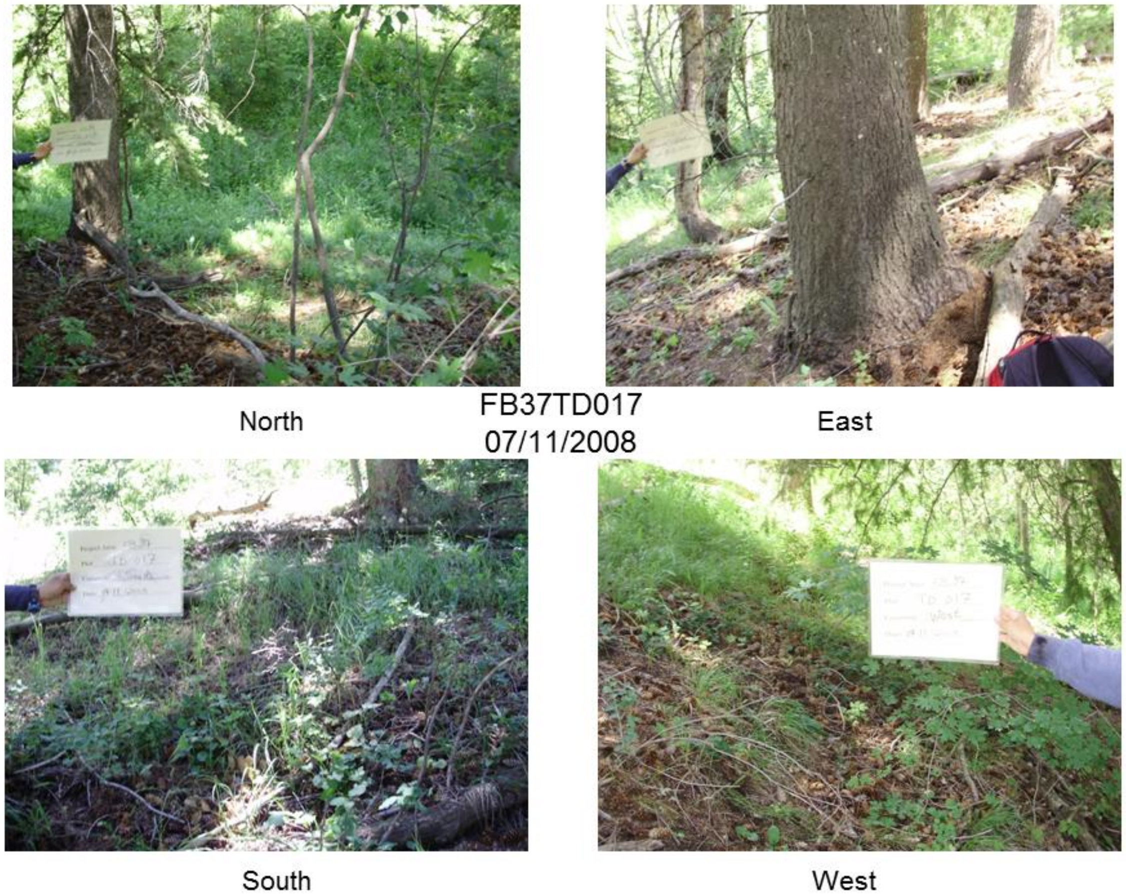


Figure A.12. Site FB37TD017 in 2008, prior to receiving cut and pile treatment the same year and broadcast burn in 2009.

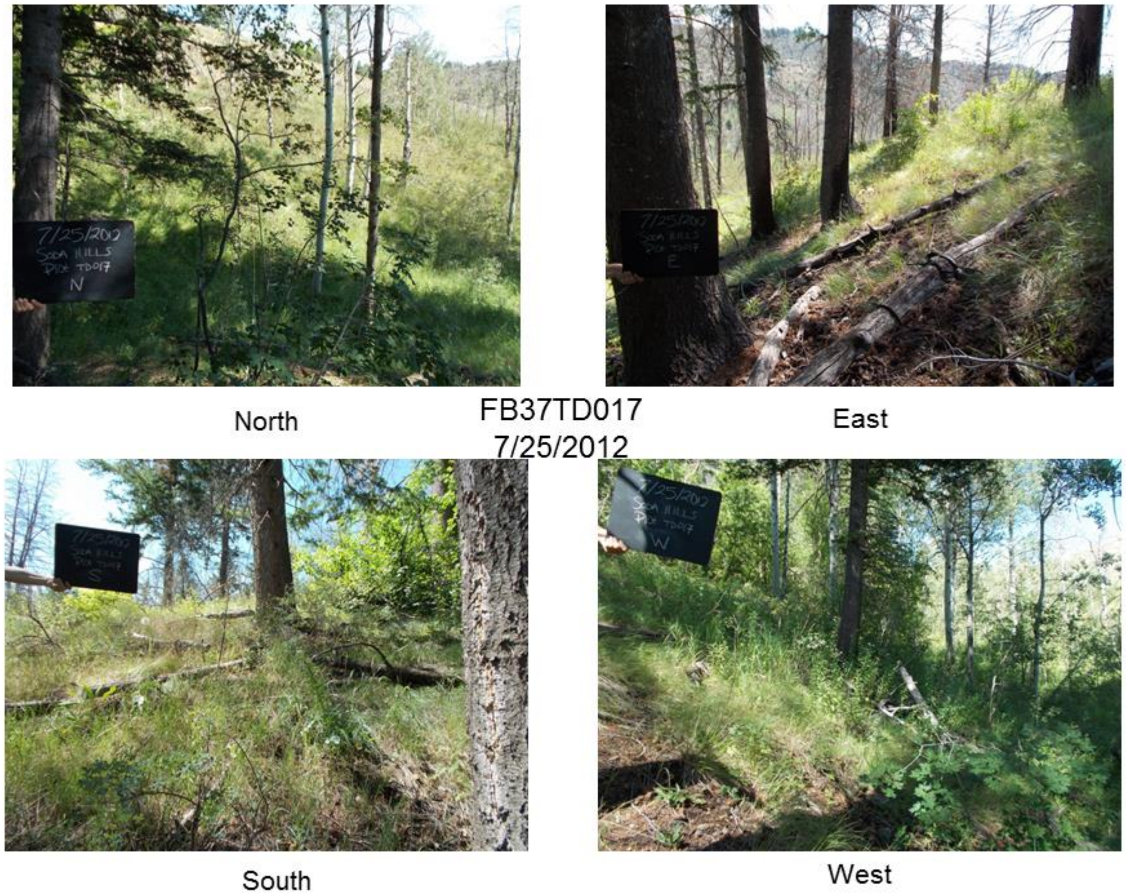


Figure A.13. Site FB37TD017 in 2012, four growing seasons after receiving cut and pile treatment in 2008 and broadcast burn in 2009.

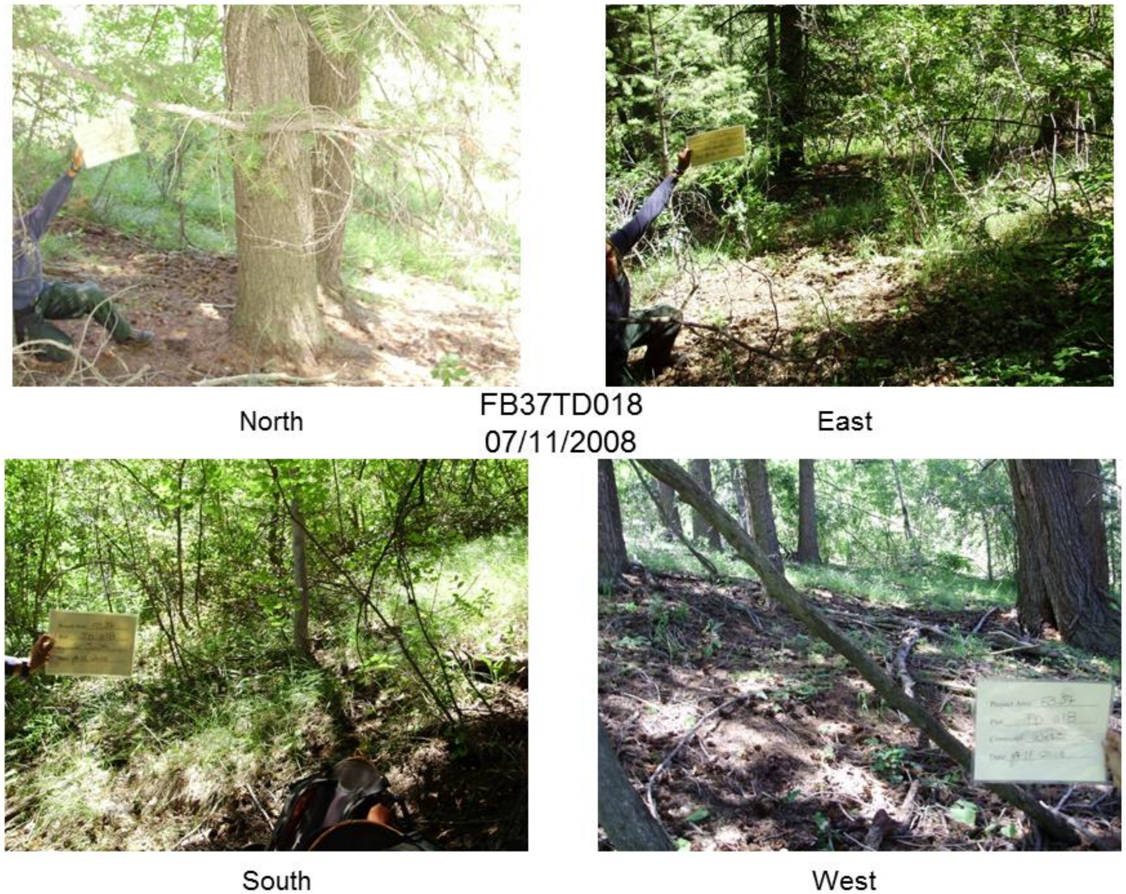


Figure A.14. Site FB37TD018 in 2008, prior to receiving cut and pile treatment the same year.

Figure A.15. Site FB37TD018 in 2012, four growing seasons after receiving cut and pile treatment in 2008.

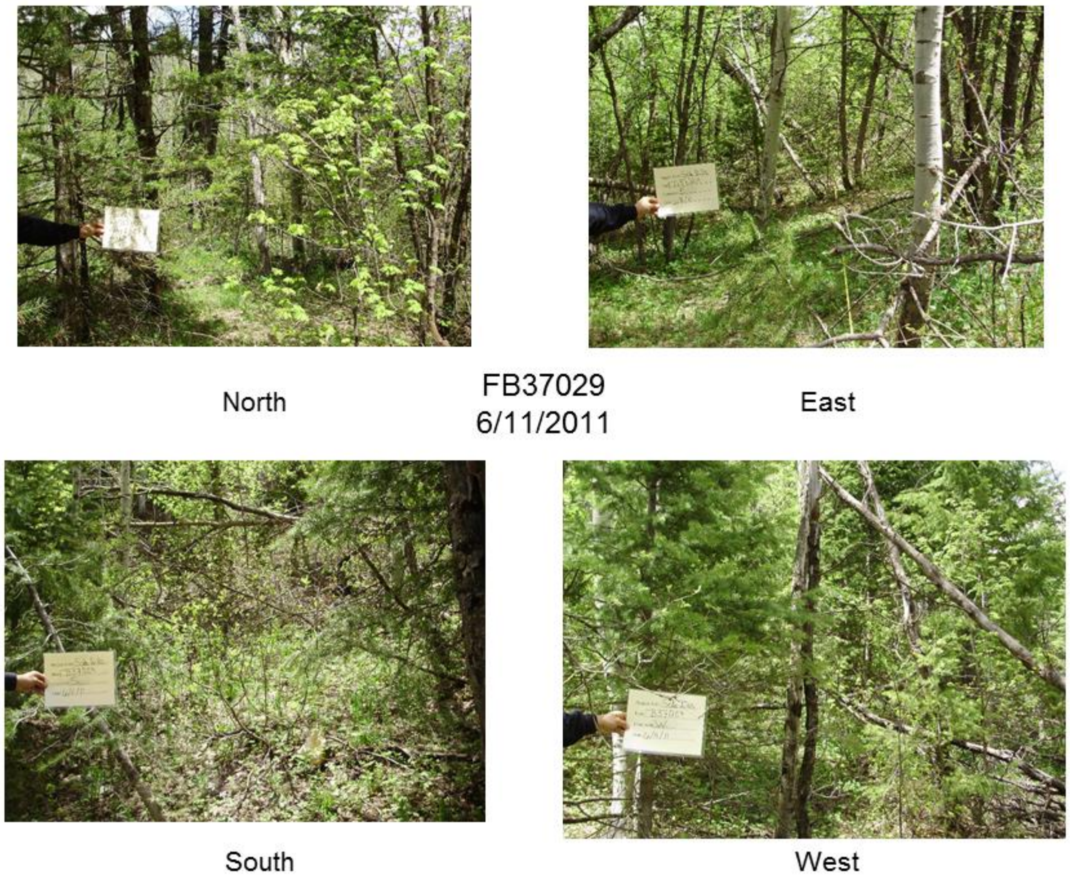


Figure A.16. Site FB37029 in 2011, prior to receiving slash/lop and scatter treatment the same year.

Figure A.17. Site FB37029 in 2012, two growing seasons after receiving slash/lop and scatter treatment in the early growing season of 2011.

North

FB37030
6/12/2011

East

South

West

Figure A.18. Site FB37030 in 2011, prior to receiving slash/lop and scatter treatment the same year.

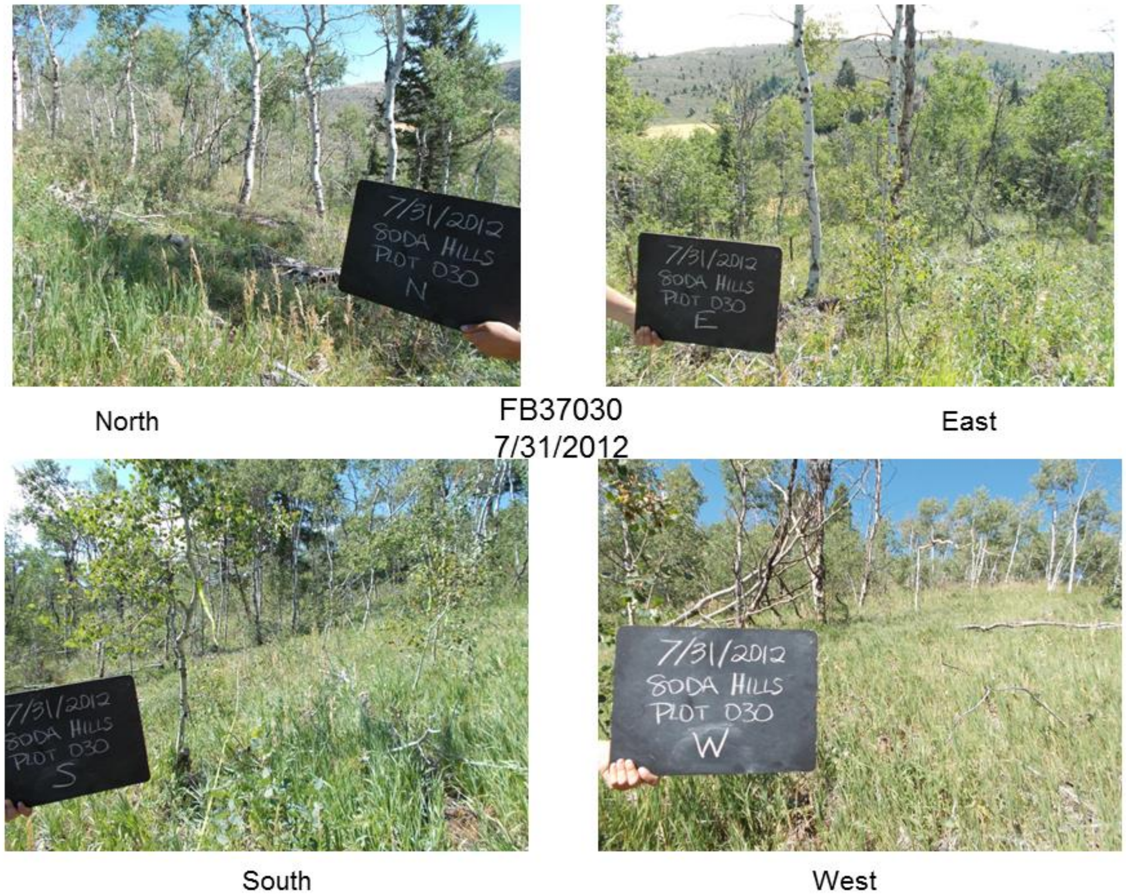


Figure A.19. Site FB37030 in 2012, two growing seasons after receiving slash/lop and scatter treatment in the early growing season of 2011.

APPENDIX B. Species Lists

Table B.1. List of all species detected in the multi-layered understory measurements, categorized by lifeform.

LIFEFORM	CODE	SCIENTIFIC NAME	COMMON NAME
FORBS/HERBS	ACMI2	*Achillea millefolium*	Common yarrow
	AGUR	*Agastache urticifolia*	Nettleleaf giant hyssop
	AMRE2	*Amsinckia menziesii*	Menzies' fiddleneck
	ARCO9	*Arnica cordifolia*	Heartleaf Arnica
	ASTER	*Aster L*	Aster
	CANU4	*Carduus nutans*	Nodding plumeless thistle
	CASTI2	*Castilleja Mutis*	Indian Paintbrush
	COPA3	*Collinsia parviflora*	Maiden blue eyed Mary
	CRAC2	*Crepis acuminata*	Tapertip hawksbeard
	CYOF	*Cynoglossum officinale*	Gypsyflower
	FRVE	*Fragaria vesca*	Woodland strawberry
	GEVI2	*Geranium viscosissimum*	Sticky purple geranium
	HAFL2	*Hackelia floribunda*	Manyflower stickseed
	HYCA4	*Hydrophyllum capitatum*	Ballhead waterleaf
	Lichen	*NA*	Lichen
	LIPA5	*Lithophragma parviflorum*	Smallflower woodland-star
	LIRU4	*Lithospermum ruderale*	Western stoneseed
	LOTR2	*Lomatium tritematum*	Nineleaf biscuitroot
	LUAR3	*Lupinus argenteus*	Silvery lupine
	LUPIN	*Lupinus*	Lupin
	Moss	*NA*	Moss
	OSBE	*Osmorhiza berteroi*	Sweetcicely
	OSCH	*Osmorhiza berteroi*	Sweetcicely
	SOCA6	*Solidago canadensis*	Canada goldenrod
	TAOF	*Taraxacum officinale*	Common dandelion
	THAR5	*Thlaspi arvense*	Field pennycress
	THFE	*Thalictrum fendleri*	Fendler's meadow-rue
	THOC	*Thalictrum occidentale*	Western meadow-rue
	TRDU	*Tragopogon dubius*	Yellow salsify
	VIOLA	*Viola*	Viola
GRAMINOIDS	AGSP	*Agropyron spicatum*	Bluebunch wheatgrass
	BRCA5	*Bromus carinatus*	California brome
	BRIN2	*Bromus inermis*	Smooth brome
	CARU	*Calamagrostis rubescens*	Pinegrass
	ELGL	*Elymus glaucus*	Blue wildrye
	POPR	*Poa pratensis*	Kentucky bluegrass
	POSE	*Poa secunda*	Sandberg bluegrass
LITTER	Litter	*NA*	Litter
SHRUBS	AMAL2	*Amelanchier alnifolia*	Saskatoon serviceberry
	MARE11	*Mahonia repens*	Creeping barberry
	PRVI	*Prunus virginiana*	Chokecherry
	ROWO	*Rosa woodsii*	Wood's rose
	RUPA	*Rubus parviflorus*	Thimbleberry
	SOSC2	*Sorbus scopulina*	Greene's mountain ash
	SPBE2	*Spiraea betulifolia*	White spirea
	SYOR2	*Symphoricarpos oreophilus*	Mountain snowberry
SOIL	Soil	*NA*	Soil
TREES	ACGR3	*Acer grandidentatum*	Bigtooth Maple
	JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper
	POTR5	*Populus tremuloides*	Quaking aspen
	PSME	*Pseudotsuga menziesii*	Douglas-fir
UNKNOWN	UNK	*NA*	Unknown
	UNK 2	*NA*	Unknown
	unk1	*NA*	Unknown
	unk2	*NA*	Unknown

Table B.2. List of all species detected in the mature tree, sapling, and seedling density measurements.

CODE	SCIENTIFIC NAME	COMMON NAME
ACGR3	*Acer grandidentatum*	Bigtooth Maple
JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper
POTR5	*Populus tremuloides*	Quaking aspen
PSME	*Pseudotsuga menziesii*	Douglas-fir