Evaluating Impacts
of Silvicultural Operations such as Thinning and Burning Treatments on Forest Health, Water Quality and Quantity in a Northern New Mexico Forest

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June 2015

1. INTRODUCTION

Managing forests for yielding water has long been lively issues, and the resulting effect on water supplies is becoming a progressively significant question for water resource managers and planners. In the Southwestern United States (US), upland of forested watersheds source water for the aim of the domestic use and agricultural usage (USGS, 2015).Within this framework, interests in the competition for fresh water is a growing matter, and controlling of water quality is needed to have regulative functions in New Mexico.

To understand effects of vegetation management on runoff and water quality, in a particular way, forests present opportunities to managers. Forests occupy 24.8 million acres of land in NM. The following species, Douglas-fir, Engelmann spruce, White fir, and Aspen have had the highest growth in volume. Ponderosa pine assigned more harvested timber volume than any other species across NM. The state of NM approximately has 94 % or 23.4 million acres of unreserved forest land.Also, over than 18 percent, or 4.3 million acres of New Mexico's unreserved forest terrestrial is categorized as timberland.Besides that the leftover 82 percent is categorized as unfertile forest land (Goeking and et al. 2014).

Over the last century, a considerable extent changes arising from intensive livestock grazing of the late 1800's (Cooper, 1960), and the past century of fire suppression (Swetnam, 1990; Weaver, 1964) have been monitored in forested areas of New Mexico. Results of livestock grazing and fire suppression on the forest can cause an increase in forest tree density (Swetnam, 1990). Increased forest stand has led to the convenient environmental area to shade tolerant species such as White fir and Douglas fir

(mixed conifer), which trespass on historical ponderosa pine stands. According to US General Accounting Office1999 (as cited in Cram,2003) ,dense stand forests picture enlarged risks in the form of extreme wildfire to species of threatened and endangered, fire safety officer, and property owners and societies . Increases in tree densities resulting from overgrazing and fire suppression have caused decreased amount of water and understory vegetation cover (Trimble and which,1987). Once thinning and burning practices are combined , forests will have the ability to increase water yields (Bosh and Hewlett,1982), and forage production (Cooper,1960) while reducing wildfire dangerous (Cram et al.,2003) .

One of the largest nonpoint source pollutant resulting from intensively practiced forest area is sediment yield (Grace,2005). Sediment yield is treatment limitation for the silvicultural operations because unproper or extensive transactions in the forested area may diminish the quality of water due to the movement of non-point source pollutants. Hence, in addition to water yield, the reaction of sediment yield to forest cutting has also been studied (Khanal and Parajuli,2013).Soil disturbance caused by silvicultural treatments will typically lead to increasing in soil erosion (MacDonald and Stednick,2003). Increases in sediment loads following forest cutting, road building, and tractor harvest are explained by increased sediment yield delivery to stream channels (Rice 1979). The significant increases in runoff and sediment yields after thinning and burning have been attributed to several factors.

To evaluate how silvicultural operations influence runoff, infiltration, sediment loading, herbaceous vegetation and forest overstory vegetation, and soil moisture in NM, more experiment is needed to conduct. In this study, the research presented attempts to

stop openings in the recent scientific literature on the hydrologic dynamics of forest management and hydrologic processes in a New Mexican forest.

The aim of this experiment was to determine the impacts of silvicultural treatments on the forested area on runoff, infiltration, sediment yield, herbaceous vegetation and forest structure, and soil moisture capacity. This research was designed based on the providing scientific information to managers for land and water with respect to helping them to manage water resources in a better way. Objectives and hypotheses stated below was intended to increase knowledge of forest management impacts on hydrologic dynamics, and provide realistic and practical information to land managers in aid of the management of the woods resources.

The primary objectives of this study are to:

1. Evaluate the effects of the silvicultural treatment on runoff, infiltration and sediment yield.

2. Determine over time responds of silvicultural forest operation to cover story and understory forest structure.

3. Conduct research in conjunction with monitoring of influences of silvicultural practices including, burning and thinning treatment on potential fuels in the form of coarse woody debris in a Northern New Mexico Ponderosa pine and mixed conifer forests.

4. Determine impacts of forest silvicultural treatment on soil moisture content during rainfall simulation experiment.

2. PREVIOUS WORK and CURRENT VIEWPOINT

A wide range of scientific research associated with forest management has been performed in the southwest part of the US, specifically in Arizona and Colorado; however for the New Mexico site limited investigation has been implemented. Along with huge knowledge of forest management studies on runoff, infiltration, sediment yield, and vegetation relevant to NM might be depicted from other states with parallel settings (McDonald & Stednick 2003).

Over the last century, a considerable extent changes arising from intensive livestock grazing of the late 1800's (Cooper, 1960) and the past century of fire suppression (Swetnam, 1990; Weaver, 1964) have been monitored in forested areas of New Mexico. Results of livestock grazing and fire suppression on the forest can cause an increase in forest tree density (Swetnam, 1990).

Increases in tree densities resulting from overgrazing and fire suppression have caused decreased amount of water and understory vegetation cover (Trimble and which,1987). Once thinning and burning practices are combined , forests will have the ability to increase water yields (Bosh and Hewlett,1982), and forage production (Cooper,1960) while reducing wildfire dangerous (Cram et al.,2003) . A study, which was reviewed for the 94 paired watershed worldwide studies, was examined to know impacts of changing of forest cover on water yield. The result have been found that 40 mm and 25 mm increase in water yield for every 10% reduction in forest overstory for the coniferous and deciduous forest, respectively (Bosh and Hewlett,1982). Also, studies have resulted out that lessening of 15% from basal area of the woods from the Rocky

Mountain region allows a quantifiable augmentation in annual water harvest (Stednick 1996).

Sustaining productive forests is a critical factor to maintenance forest soil (Curran et al. 2005). Soil is a reservoir for water and provides the standard conditions for plant growth.Disturbance of soil caused by silvicultural treatment and catastrophic fire influence runoff and infiltration due to changes in soil moisture content. Once soil moisture increases, soil pores come in possession of filled with water. Bowyer-Bower 1993, Azooz and Arshad 1996 mentioned (as cited in Madrid,2005), at this moment, runoff and infiltration processes result in the form of increases and decreases, respectively. Throughout the duration of simulated rainfall, monitoring the moisture content of the soil may aid to verbalize difference in infiltration and runoff (Madrid,2006).

Enhanced water resource management is a vital element to understand better influences of forest practices on water quantity and quality. Silvicultural operations have been assigned to be an influential technique for gathering water from upland watersheds in a forested area (Bosh and Hewlet, 1982). As a result of this determination, widespread experiments has been established by hydrologist with respect to impacts of silvicultural treatments including clearcutting, removing or thinning of forest overstory. Despite the fact that silvicultural treatments have been found an effective way to increase water yield through forested watershed area (Bosh and Hewlett,1982); however, this management ways can also cause adverse ecological impacts on forests (Binkley and

Brown,1993).Therefore, the enhanced balance should be considered to keep the forested area healthy while applying silviculture practices.

According to Whelan, 1995; Kaye and Hart, 1998; Huffman and Moore, 2004; Gundale et al., 2005 (as cited in Dadson,2008),thinning followed by prescribed fire can serve modifications on understory vegetation by damaging or killing plant life, releasing resources and encouraging germination of seeds deposited in canopy seed banks and territory) . Moir, 1966; Ffolliott and Clary, 1982; Uresk and Severson, 1989; Riegel et al., 1992; McPherson, 1997; Scholes and Archer, 1997; Naumburg and DeWald, 1999 found that (as cited in Dadson,2008),thinning and prescribed burning may also amend understory vegetation in a roundabout way by changing overstory tree cover and density and their influences on understory microclimate, light, soil water, and nutrient availability . Thinning forest also increases the percentage of understory vegetation by changing light conditions under the forest canopy (Yanai et al., 1998; Thomas et al., 1998). These changes may have a significant role in soil infiltration capacity and runoff process.

3. EXPERIMENTAL PROCEDURES

3.1 Study Area

Walker Flats site area (Latitude 36° 00'58.15"N, Longitude 105° 27'37.78"W) has a 608-acre grazing allotment in the Santa Fe National Forest in the Pecos/Las Vegas Ranger District near Mora, NM. There are three units that represent the Walker Flats site area: Walker Flats Unit (270 acres), Encinal Unit (140 Acres), and Corrales Unit (198 acres). The elevation ranges from 8800 ft. to 9600 ft. The site varies between timber stands of ponderosa pine, mixed conifer, and aspen. Gentle slope and steep slope are typical slopes for the site. The gentle slopes have an average of 5% slope while steep

slopes have an average of 20% slope. The overstory vegetation of the stands is classified as two different types of forest stands. The first is a Ponderosa Pine stand, where the composition of the stand is more than 60% Ponderosa Pine (*Pinus ponderosa*). The second stand is a Mixed Conifer stand, in which Ponderosa Pine is less than 60% in composition, the other dominant tree species in these stands are White Fir (*Abies concolor*), Douglas Fir (*Pseudotsuga menziesii*), and an Aspen (*Populus tremuloides*) component.

Representative spots were determined by using the data from the old study. Each site was a combination of a dominant species stands type and slope. The four sites of both Ponderosa Pine stands at 5 and 20 percent slopes, and Mixed Conifer stands at 5 and 20 percent slopes were identified for research. The Walker Flats CFRP project consisted of numerous stands that had received a variety of thinning treatment and burning practices spanning until fall 2008. The thinning experiment was applied before the fall of 2008. In the fall of 2008, the experiment of burning was conducted in the site area. Prior to ongoing research, another study was conducted in the study area beginning from 2003 through the year of 2009 associated with forest health and forest hydrology.

3.2. Forest Inventory

Prior to treating and after the treating the forest, timber inventory is necessary to provide a benchmark for the project. In addition to initial inventory, post-treatment forest inventory performed in summer of 2014 on the determined area from the previous study for the walker flat unit. Existing plots, which had been already laid out in 2003 for the monitoring project depending on the site characteristic plots, was decided to use to compare changes on forest health over time. Circular Fixed Area Plot (CFAP) was

chosen to apply for the forest inventory across to these plots. The dimensions of the circular fixed area plot were determined based on the minimum distance between plots. 1/40 plot area was used as a function of per unit area.Circular radius was characterized in about 19 feet for every single circular plot. In the plot sampling site, it was assumed that the plot area is representative in the remainder of the field of interest.

The following parameters were measured by using circled fixed area plot method: Basal area, tree species, DBH of tree and tree height. For the timber inventory plots on the Walker Unit, the average slope was measured with a clinometer in the downslope direction. The diameter of trees was classified into Seedlings (< 3 cm), Sapling (<14 cm), Poles (< 24 cm), and Sawlogs (>24 cm).Diameter at breast height (1.30 m) was measured by using calipers. Tree height was measured in meter by using Nikon Forestry 550 laser rangefinder.

3.3. Soil

In addition to soil samples in 2009, in 2005 another soil samples were taken, and the soil texture content has started to be analyzed. Soil sampling was collected from the each plot to determine if there were systematic patterns in soil moisture or texture that would make it difficult to analyze treatment effects grouped by a slope or by tree species. The soil samples were taken close enough to the plot boundary in the direction of North and South face by opening soil layer. The soil layer was determined in three increments; 0-5cm, 5-15cm, and 15cm to final soil depth. Soil texture was determined by the hydrometer method. Prior to rainfall simulations, soil core (0-5 cm depth) was taken next to each plot, and stored in a labeled plastic bag to determine gravimetric antecedent moisture content and bulk density. Bulk density samples were taken at a 0-5 cm depth

following the core method (Blake and Hartage, 1986) and oven dried for 48 hours at 105 C prior to weighing.

3.4. Vegetation Sampling

 0.5-m × 1.0-m rectangular quadrat was used to measure percentage vegetation cover through the fixed circular plot. Sampling of vegetation cover was taken the directions of North and South face starting from plot center with five repetitions. The rectangular quadrat (0.5 square meters) was divided into the different classification of percentage.

Ground cover was broken up into the following categories: grass, forb, shrub, rock, bare ground (soil), broad leaf, twigs, and needles leaf. Litter was considered as an accumulation of broad leaf, twigs, and needles leaf. Canopy cover was measured with a spherical densitometer by taking the average of measurements when facing north, east, south, and west directions from the plot (Lemmon 1956). No aerial cover of plants was recorded. The percentage of vegetation cover was categorized with visual (ocular) estimation method.

3.5. Coarse Woody Debris (CWD)

Coarse woody debris (CWD) is defined as dead downed woody material in various stages of decomposition, including fresh and rotting logs, snags, stumps and large branches (Harmon and Sexton, 1996) on the ground surface in the forested area. CWD measurement plays many roles in the forest ecosystems (Brown et. all, 2002). Examination of the ecology of CWD may help us to understand potential fire

performance and fuel accumulations in a forested area (Brown and et. all, 2003).In this study, we also examined the CWD to calculate potential fuel loads and the potential for fire. There are numbers of designed methods to assess CWD on fixed area plot sampling (Gove and Deusen, 2011). In our study, we used a new method that is called Gove and Deusen developed the 'sausage method' on behalf of Institute of Chartered Foresters. The protocol of the sausage method is to measure any pieces of CWD that falls or lies within a fixed circular plot area (Gove and Deusen, 2011).

We used the plot radius as a function of addressing the inclusion zone. According to the protocol of the sausage method, we recorded the following variables; species, the small and large diameter of woody materials in cm, and length of the woody materials in a unit of meter. Coarse woody debris is typically addressed as dead standing and downed pieces larger than 3 inches in diameter (Harmon and others 1986), and also some ecologists defined the woody material larger than1 inch in diameter. For the purpose of this study, we defined the CWD as fallen logs and considered the CWD for the large part of downed log equal or greater than 7.5 cm in diameter and for the small pieces at least 3 cm in diameter. In addition, we determined decay classification based on Maser `s et al. (1979) classification system.

The dead woody debris typically is grouped by ecologists and fire managers based on the diameter of the derbies. 1-, 10- and 100-hour fuels are named "fine woody debris'', and 1,000-hour fuels are termed as "coarse woody debris (Lutes and Keane, 2006). By reason of studying on the CW, we termed the fuel loads for 1000 hours. In order to calculate the volume of the CWD, we used   Smalian's formula. This formula

was the appropriate for the sausage protocol because this equation requires measurements of small and large end diameter, and length of the log as in the protocol of the sausage method. We considered that all fallen logs were a paraboloid.

The Smalian's formula: $V = ((A + a)/2) \times L$

Where;   V = Volume in cubic meter (meter3)

     A = Large-end cross-section area (meter2)

     a = Small-end cross-section area (meter2)

     L = Length of the log (meter)

3.6 Simulator Design

The main part of this study is to determine the water quality and yield after silvicultural treatment. In order to do that the best way is to simulate a rainfall application. A portable rainfall simulator (Wilcox et al. 1986) fitted with a ¼G10 full jet nozzle (Spraying Systems Co. Wheaton, Ill.) was installed to provide controlled conditions for evaluating infiltration, runoff, and sediment yield. This type of simulator was used on steep slopes in the Guadalupe Mountains; yielding drop sizes produced by the ¼G10 full jet nozzle are smaller than natural rainfall at the same intensity (Wilcox et al. 1986). Due to the smaller size of drops produced by the ¼G10 full jet nozzle, kinetic energy of a simulated rainfall of 10 cm hr.$^{-1}$ is only about 36% of a natural rainfall event of the same intensity (Wilcox et al. 1986). Rainfall simulations was conducted with the nozzle positioned vertically downward within a tripod at 175 cm above from the soil surface. The rainfall simulation is ongoing experimental and will be finished mid of the July in 2015.

3.7. Rainfall Application

Rainfall simulations was conducted in the summer of 2015 under the two different conditions on square meter circular runoff plots.The first condition was dry run that was under antecedent moisture conditions, and another one was wet run that is about 24 hours later at field capacity. For each rainfall simulation, we used 10 pounds per square inch (PSI) pressure precipitation thoroughly simulator. After the dry run, plots was covered with a tarp to eliminate evaporation and ensure soils were at field capacity prior to wet runs. Two rain gauges was installed near the center of the plot and rainfall was measured at five-minute intervals. We pumped the water from a 200-gallon water spray tank to the rainfall simulator through a garden hose with a Pacer water pump powered by a 5.5 horsepower Briggs & Stratton engine.

3.8. Plot Setup

The plot rings were placed on the runoff tray in the downslope direction and pounded into the ground with a sledgehammer until the tray is leveled with the soil surface. During plot installation, soil approximately was slightly disturbed. A hand level one meter in length was used to measure the slope of each plot. A small screen was installed over the runoff tray to prevent pine needles and small twigs from entering the runoff collection tank. A 1.5 meter, clear 4.44 cm diameter (1-¾ inch) hose was clamped to the spout of the runoff tray at one end and laid into the collection tank at the other end. This application ensures that overspray from the simulator will not be collected as runoff. The runoff collection bucket was always installed lower than the runoff spout to prevent any slowing of runoff. Time to the runoff was recorded after first runoff have seen in the

collection tank. Runoff was collected and measured every five minutes. Infiltration was calculated as the difference between the amount of water applied and the amount of runoff collected.

4. Results and Discussion

4.1. Over Story Forest Characteristics

4.1.1. Stand Composition

In this section, forest health compared through the years of 2003 and 2014 based on different plot layouts. In 2003, at the time of the initial inventory, white fir made up the highest percentage of trees at 33% compared to other existing species. It was monitored that white fir had percentage of trees at 17% in the year of 2009 while recording at 7.3 % in 2014 which was the lowest rate of occurrence of white fir over time (Figure 1). In 2003, ponderosa pine made up a percentage of trees at 29%. Ponderosa pine generated 35% and 11 % of the stand composition in the experimental area in 2009 and 2014, respectively (Figure 2). Douglas fir occupied at 23%, 31% and 46.7 % in the years of 2003, 2009 and 2014, respectively (Figure 3). These inventories showed that Douglas fir became the highest percentage of trees in 2014.Forest inventory data displayed that occurrences of aspen trees increased over time. Aspen trees was recorded at the percentage of 14 in 2003, 16% in 2009 and 21% in 2014 (Figure 4). Gamble oak did not have a settlement for the year of 2003 and 2009; this tree species occupied 7.3 % of the experimental area in the year of 2014 (figure 5) ,which could be because of right after burning some species such as gamble oak and aspen occupy the burned area if they have settlement nearby the burned area. As a summary, these inventories explained that

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the white fir was dominant in 2003 but is now at a much lower density in the forest. Ponderosa pine is once again the most dominant tree in 2009, as it was historic. In 20014 Douglas fir became dominant tree as in 2003.This can be because of once the Douglas fir finds the appropriate environment to shade, Douglas fir encroaches the other species such as ponderosa pine.
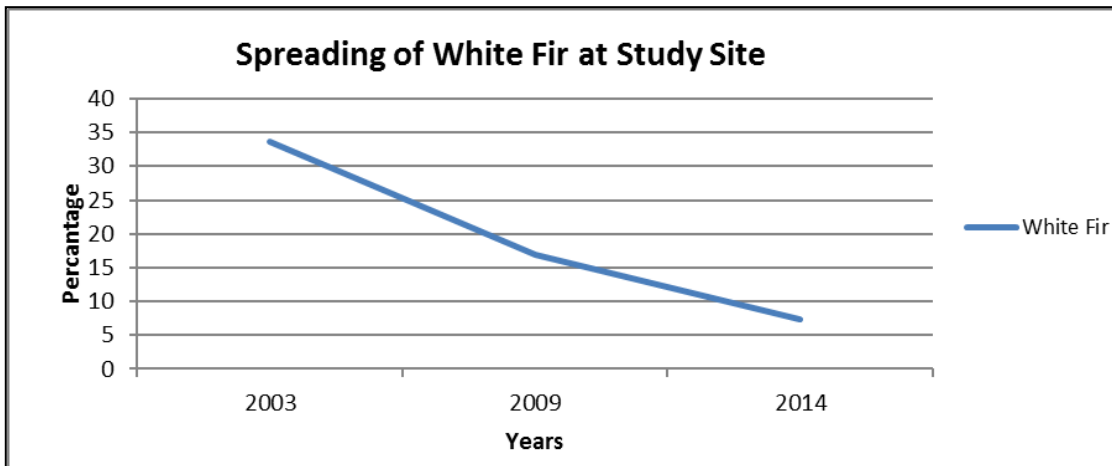

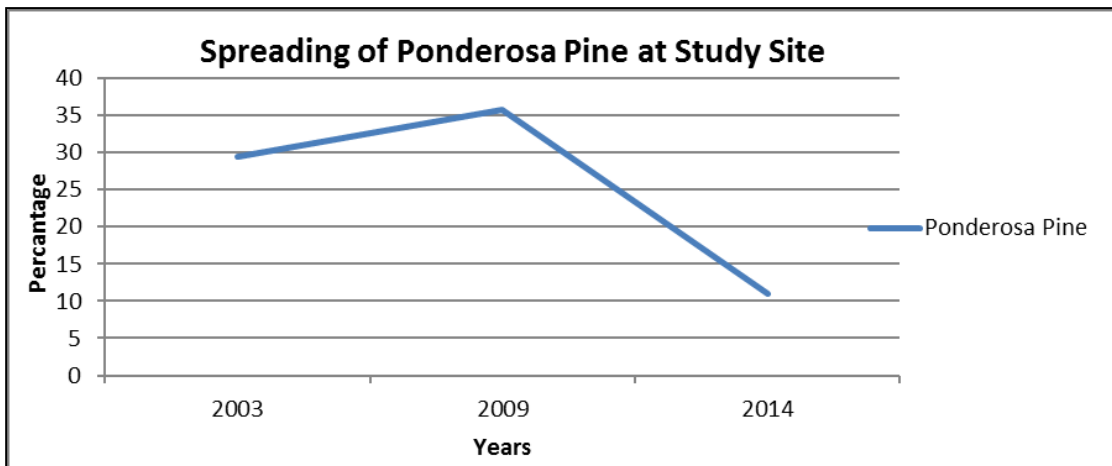Figure 1. Distribution of White Fir Species at the thin and burn study area over time

Figure 2. Distribution of Ponderosa Pine Species at the thin and burn study area over time
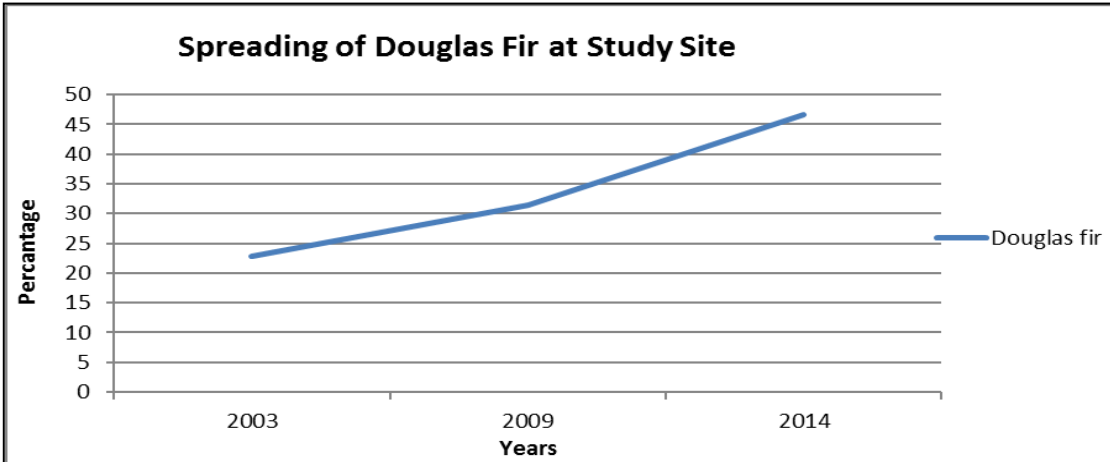
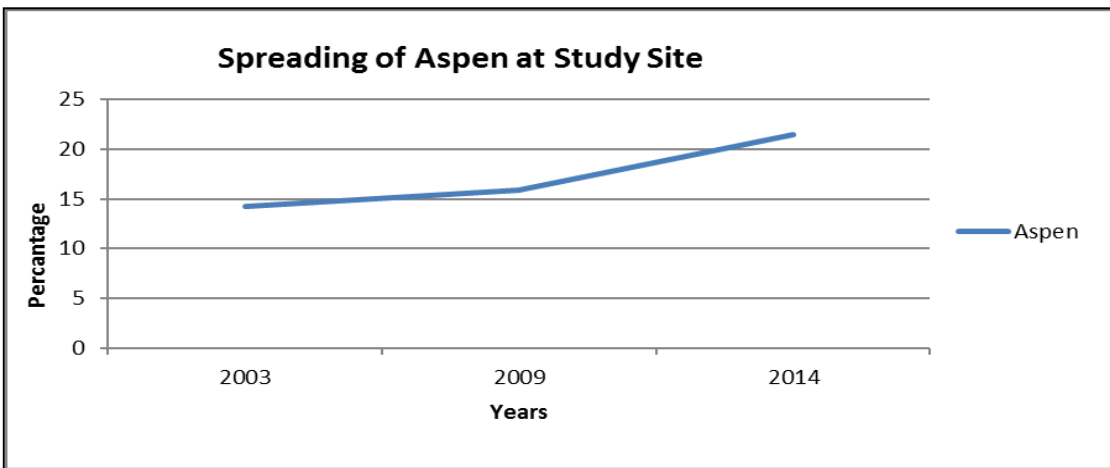Figure 3. Distribution of Douglas Fir Species at the thin and burn study area over time

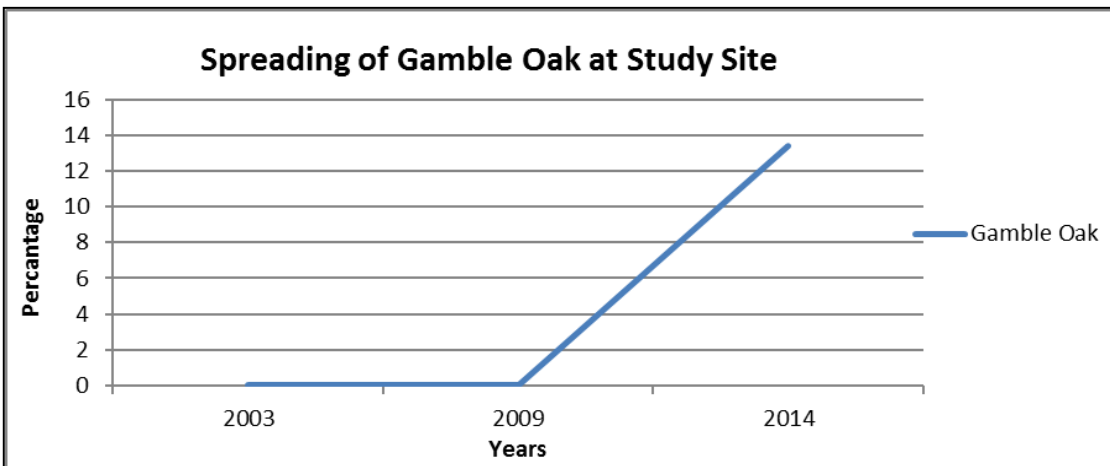Figure 4. Distribution of Ponderosa Pine Species at the thin and burn plots over time

Figure 5. Distribution of Gamble Oak Species at the thin and burn plots over time

4.1.2. Basal area, number of seedlings and canopy cover

The basal area dropped by 21% post thinning from 135 ft² per acre to 107 ft² per acre from the timeline in 2003 to 2009.The experimental site had the basal area of 130.8 ft² per acre in 2014 which was the enough close value as at the beginning of the thinning treatment (table 1).This explains that basal area may need more than five years to reach a post-conditions value as a volume.

The number of seedlings is increased from an average of 880 to 1400 seedlings per acre from 2003 through 2009; this increases also continued 2014. Number of seedlings in 2014 was 2200 per acre (table 1). These data show the silvicultural operations such as thinning and burning treatment was effective at decreasing the basal area and opening the canopy that has allowed more seedlings to grow. This reduction in the basal area should also encourage understory herbaceous vegetation growth.

Table 1. Forest Inventory on the three units of the Walker Flat Research Site for the Mora Collaborative Forestry Project in 2003, 2009 and 2014.

Attribute	2003		2009		2014	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
# Seedlings per acre	880	950	1400	1360	2200	1360
BA (ft^2/Ac)	135.2	59.5	107.3	53.6	130.8	79.8

The canopy cover for control sites in 2009 and 2014 was much higher than the canopy cover of treatment sites (figure 6). The reduced canopy cover in the treatment transects displayed that the treatment was effective in allowing more light into the understory for herbaceous plant production.
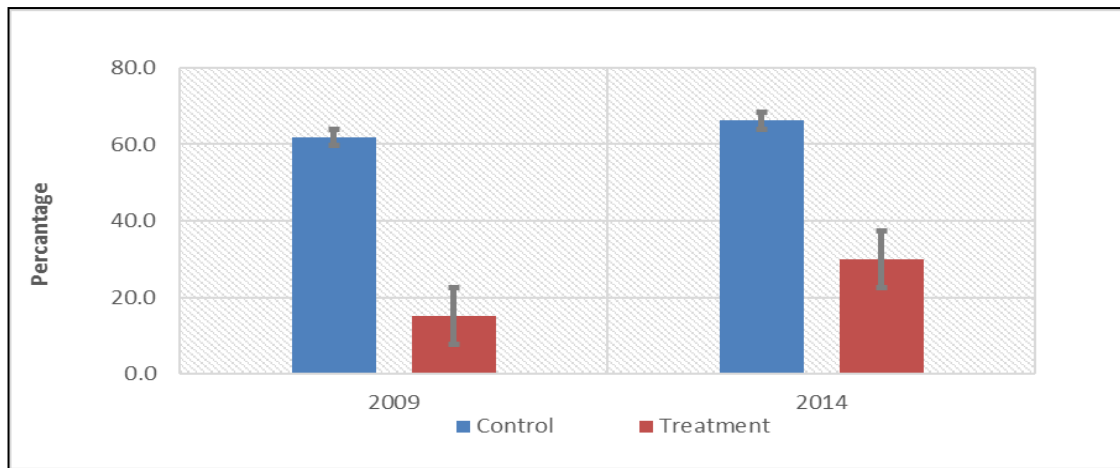

Figure 6. Percentage of Canopy Cover at the thin and burn plots in 2009 and 2014. Error bars represent the mean.

4.2. Under Story Forest Characteristics

4.2.1.Pre and Post Treatment Understory Cover

The percent ground cover had some changes in pre and post-treatment at the thin and burned plots over time. In 2008, interspace sites had higher levels of vegetation in the treatment sites and also was higher than control sites. Litter cover had the slightly highest rate in the control sites comparing to treated sites. This probably due to having a higher tree density, therefore having greater amounts of tree litter. Lop and Scatter sites had more litter than vegetation this may because of high amounts of litter that may have prevented more vegetation growth in the areas where there was more available sunlight (figure 7).
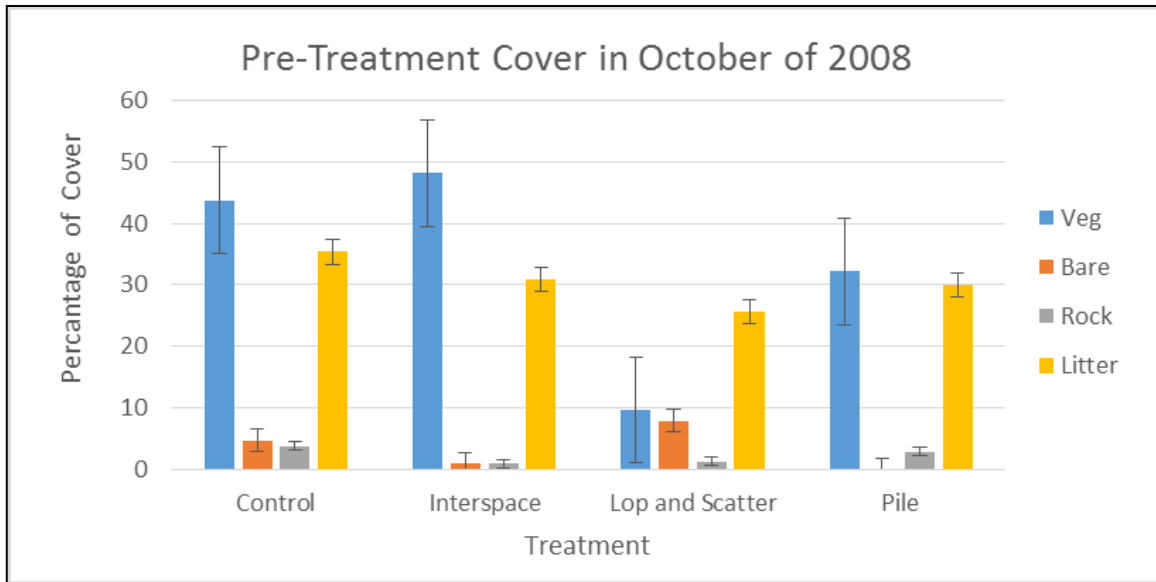
Figure 7. Percent vegetation cover at thin and burn plots by treatment before burning in fall of 2008. Error bars represent the mean

In 2009, when burning treatments took place, vegetation levels decreased at the lop and scatter and interspace sites. Also, the decreases were seen in vegetation from 2008 to 2009 at the control sites. The reason could be due to much higher amounts of precipitation in the summer of 2008 leading to higher amounts of plant growth, and lack of rainfall in 2009.In the pile sites, no vegetation was recorded this was because of heavy burning in these areas. Overall, treated areas had less vegetation growth potential that may be due to treated sites only had one growing season to re-grow after burning treatment.This may cause not to have sufficient for recovering the vegetation compositions when combined with lower amounts of precipitation (figure 8).
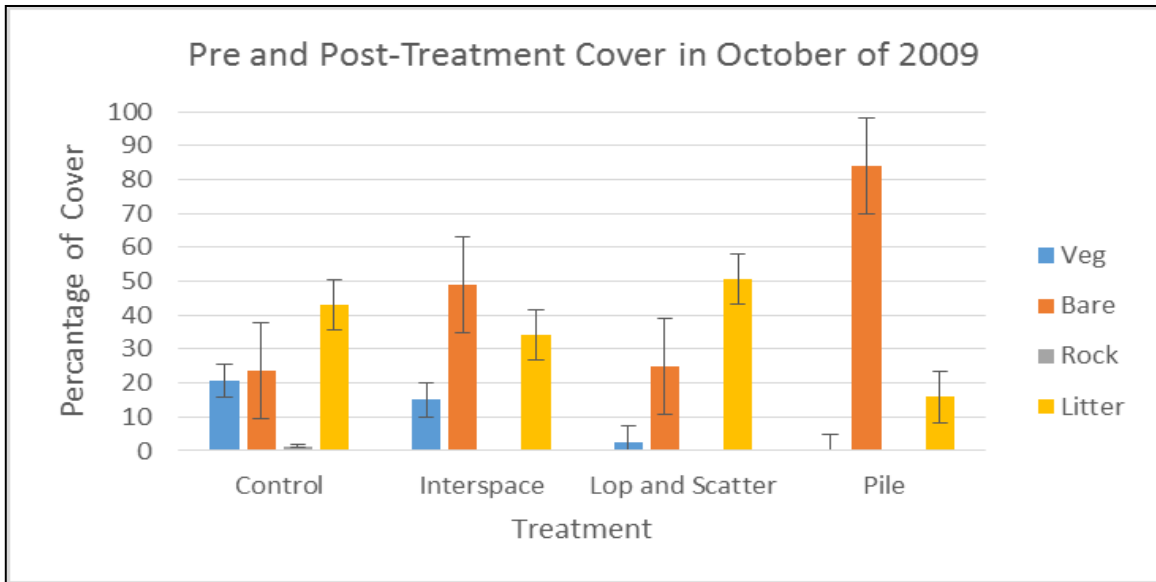
Figure 8.Percent vegetation cover at thin and burn plots by treatment after burning in fall of 2009. Error bars represent the standard deviation.

In 2014, the vegetation cover increased at treated and untreated sites because the areas got more than one year to growth again.Litter was highest, and vegetation growth rate was the lowest percentage in control sites.It could be explained that overgrazing on control could occur that might allowed to large litter and less vegetation. At all locations, the bare soil was less because of large amounts of litter cover (figure 9).
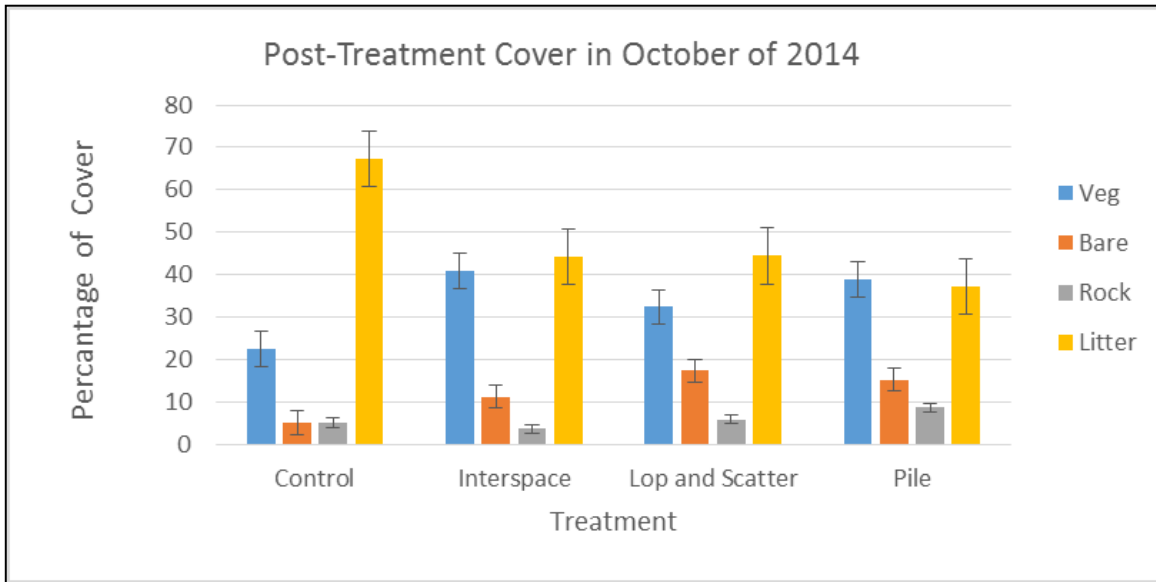
Figure 9.Percent vegetation cover at thin and burn plots by treatment after burning in fall of 2014. Error bars represent the standard deviation.

4.2.2.CWD

CWD volume by decay class was found different between control and treated plots. More CWD was lower in decay stages (2) in the control than in treatment while CWD was bigger than in decay class(3) in control sites than treated areas. Generally, CWD in later decay stages (4-5) was rare in both fields.
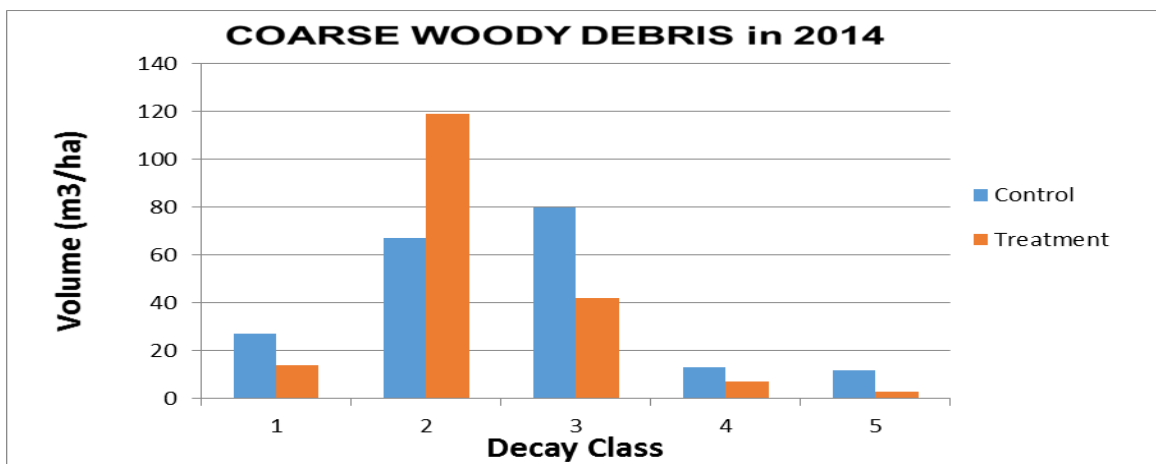

Figure10: Volume of CWD by class for the control and treatment sites at study area.

5. Rainfall Simulations at the thin and burn study areas in 2009 and 2015

5.1. Rainfall Simulation in 2009

In 2009, the rainfall simulation resulted in the study site of thin and burn treatments showed rainfall simulation plots had similar characteristics. . All slopes averaged around 18% (inter-space 19 ± 7%, lop and scatter 17 ± 12%, and pile 19 ± 11%) except for the control sites which averaged at 6 ± 6% (a steeper sloped control site was not available). The soils were found to be sandy loam or loamy sand soils, all sites having approximately 75% sand or more.

The thin and burn study rainfall simulations in 2009 showed the treatments had little effect on the amount of runoff seen as all treatments were very similar to the control, which also had a much lesser slope. The runoff at all sites was less than 0.5% (figure 11). Pile plots had the highest amount of runoff due to one higher runoff plot, but it was still a very small amount. The dry runs had a slightly higher amount of runoff at the interspace plots, and all others including the control had higher runoff during the wet runs. The infiltration rates were very high at all plots; all above 99% (figure 12). These results display that none of the treatments created large amounts of runoff in general or when compared to the control plots.
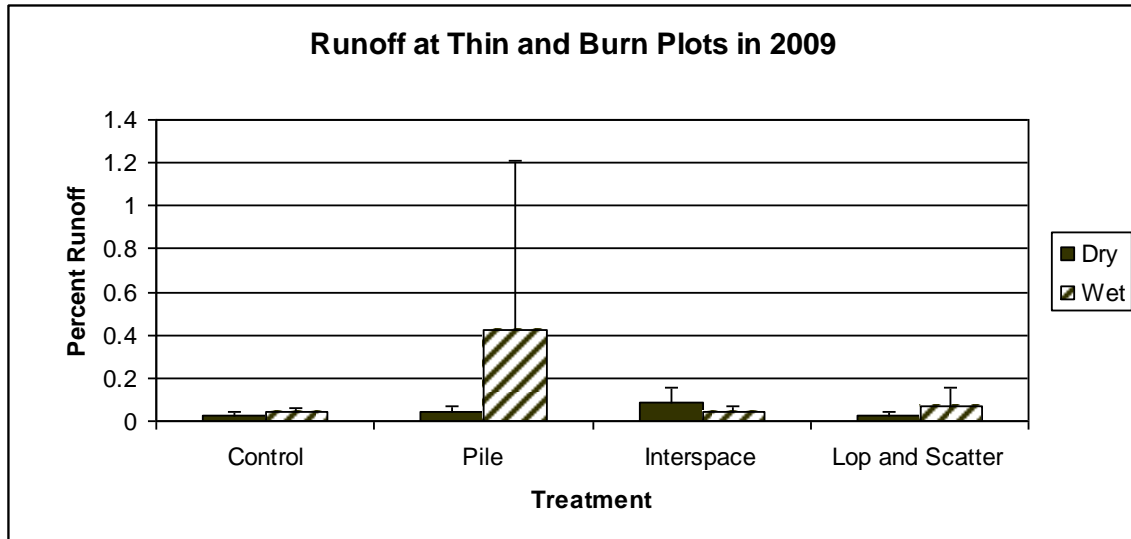
Figure 11. Rainfall simulation runoff at the thin and burn plots by treatment and run in 2009. Error bars represent the standard deviation.
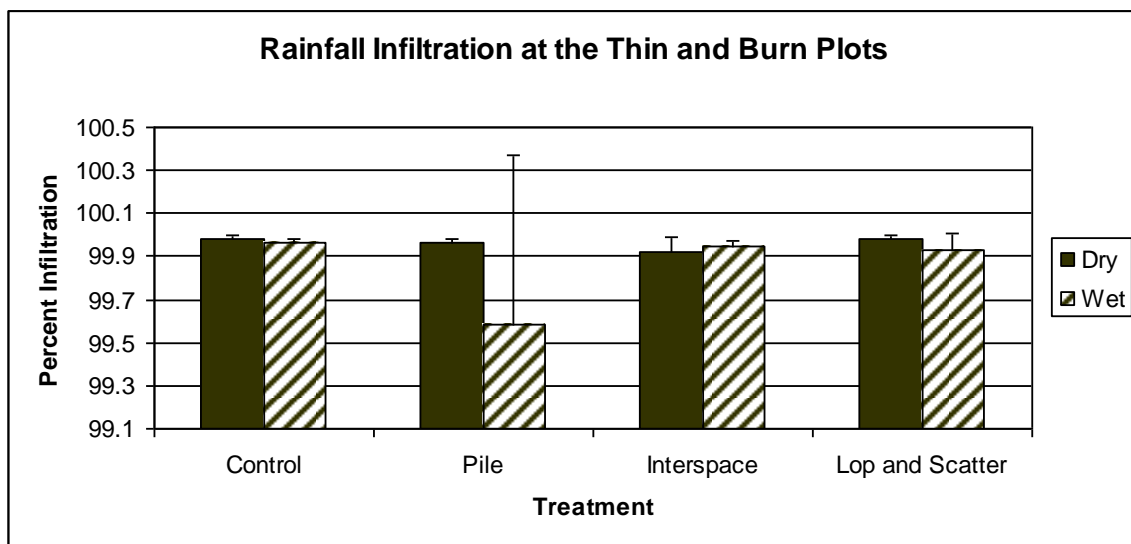

Figure 12. Rainfall simulation infiltration at the thin and burn plots by treatment and run in 2009. Error bars represent the standard deviation

The sediment yield at all the treatments yielded small amounts with the highest being less than 1.5 pounds per acre (figure 13). All treatments were similar to the control plots in both the dry and wet runs. Control had a slightly lower yield than all treatments except for the lop and scatter dry run and the inter-space wet run. Control was even between the wet and dry runs. Lop and scatter had a higher amount of yield during the

wet run than in the dry run. No treatment stood out as resulting in higher amounts of sediment yield and all were at a relatively low level showing that the thin and burn treatments did not produce large amounts of sediment loss in general or when compared to the control. This conclusion was also reached by a study in a southern New Mexico mixed conifer forest where low sediment yields occurred after partial thinning of the forest (Madrid et al., 2006). This data supports the study findings showing that the thin and burn treatments were not detrimental to forest health.

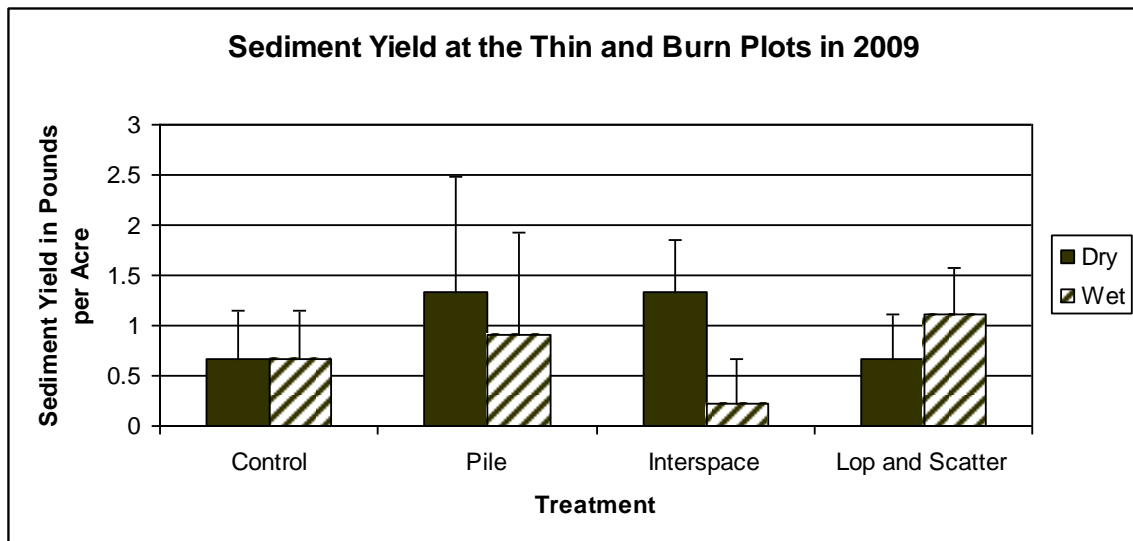Figure 13. Rainfall simulation sediment yield at the thin and burn plots by treatment and run in 2009. Error bars represent the standard deviation.

5.2 .Rainfall Simulation in 2015 (continued study)

The experiment is still ongoing and will be resulted in the mid of July.

Financial Support

New Mexico Water Resources Research Institute
New Mexico Commission on Higher Education
New Mexico State University Range Improvement Task Force
Republic of Turkey Ministry of Forestry and Water Affairs/General Director of
Combating Desertification and Erosion
Republic of Turkey Ministry of Education

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Cooperation

United States Forest Service (USFS)
Mora/John T. Harrington Forestry Research Center

Appendix

Table A.1. Soil texture and bulk density at each rainfall simulation plot in the thin and burn study area.

Block	Treat	Plot	Sand	Clay	Silt	Bulk Density	Texture
1	Control	1	79.84	12.16	8.00	1.56	Sandy loam
1	Control	2	80.84	12.16	7.00	1.56	Sandy loam
2	Control	1	80.84	11.16	8.00	1.57	Sandy loam
2	Control	2	81.84	10.16	8.00	1.59	Loamy sand
1	Inter-space	1	76.84	17.16	6.00	1.5	Sandy loam
1	Inter-space	1	74.84	12.16	13.00	1.55	Sandy loam
2	Inter-space	1	84.84	8.16	7.00	1.63	Loamy sand
2	Inter-space	2	83.84	9.16	7.00	1.61	Loamy sand
1	Lop & Scatter	1	76.84	14.16	9.00	1.53	Sandy loam
1	Lop & Scatter	2	76.84	14.16	9.00	1.53	Sandy loam
2	Lop & Scatter	1	78.84	12.16	9.00	1.56	Sandy loam
2	Lop & Scatter	2	78.84	12.16	9.00	1.56	Sandy loam
1	Pile	1	76.84	17.16	6.00	1.5	Sandy loam
1	Pile	2	74.84	12.16	13.00	1.55	Sandy loam
2	Pile	1	84.84	8.16	7.00	1.63	Loamy sand
2	Pile	2	83.84	9.16	7.00	1.61	Loamy sand

Table A.2. Runoff, infiltration and sediment yield from rainfall simulations in the thin and burn study areas conducted in fall of 2009.

Measure	Run	Control		Inter-space		Lop and Scatter		Pile	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
% Run-off	Dry	0.02	0.02	0.08	0.02	0.02	0.02	0.04	0.02
	Wet	0.04	0.02	0.05	0.79	0.07	0.08	0.42	0.79
% Infiltration	Dry	99.98	0.02	99.92	0.02	99.98	0.02	99.96	0.02
	Wet	99.96	0.02	99.95	0.79	99.93	0.08	99.58	0.79
Sediment Yield Lb / acre	Dry	0.67	0.47	1.34	0.52	0.67	0.45	1.34	1.15
	Wet	0.67	0.47	0.22	0.45	1.12	0.45	0.90	1.03

Figure 14. Study site: Mora, NM –Walker Flat

Figure 15. Control Site at Thinning and Burning Study

Figure 16. Treated site at Thinning and Burning Study

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