Rogue Basin Upland Recharge Project

A Feasibility Study of Hydrogeological Infiltration Processes

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Abstract

Studies show that it is feasible to conserve water by detaining precipitation that falls on rural lands during the wet season, minimizing runoff and increasing infiltration, providing base flow for instream and agricultural use by adding organic material and other amendments into upland soils. Climate change in the Rogue Basin is projected to result in less precipitation falling as snow resulting in smaller snowpack's; earlier snowmelt; increased incidence of rain-on-snow flooding; reduced dry season stream flows; greater moisture stress on vegetation; and increased stress on aquatic ecosystems. Studied techniques for water infiltration include biochar, mulching, and cover cropping which have all been used in this feasibility study. The expected outcome of this research is to provide empirical evidence and research on how soil amendments affect water infiltration in the Rogue Basin. As a feasibility study this research will provide a foundation for large-scale studies and implementation.

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Introduction

The Rogue Basin will be substantially affected by climate change. Overall, warming temperatures will result in less precipitation falling as snow, resulting in smaller snow packs; earlier snowmelt; increased incidence of rain-on-snow flooding; reduced dry season stream flows; greater moisture stress on vegetation; and increased stress on aquatic ecosystems. Droughts and floods are likely to increase, both in frequency and severity, which is already occurring in many areas across the country (Myer, 2013). With snowpack from the Cascades and Klamath---Siskiyou Mountains, providing much of the critical groundwater recharge and spring runoff, the region is at high risk of decreasing water availability with a shift in climate (Rogue Restoration Action Plan, 2015). The hydrologic cycle stores water during the winter months November–March when precipitation is highest, and provides melt water that recharges aquifers and sustains streams during the drier months of the year June–September (Sproles, et al. 2013). Rising temperatures will likely cause precipitation to fall as rain at lower elevations rather than as snow on peaks so average January snowpack will decrease; by 2035 – 2045 snowpack may be reduced 60 – 65% and by 2075 – 2085 as much as 90%. This will likely reduce run-off during late summer / fall and substantially reduce available irrigation and drinking water (Myer, 2013).

Each year, more of the precipitation that falls in the Rogue Basin flows quickly out to the ocean during the wet season rather than infiltrating into the soil where it is conserved for use in the summertime. Studies show that it is feasible to conserve water by detaining precipitation that falls on rural lands during the wet season, minimizing runoff and increasing infiltration, providing base flow for instream and agricultural use by adding organic material and other amendments into upland soils.

The principle source of water in the Rogue Basin is groundwater which is recharged by infiltration into the soil by rain and snow events. The average well depth in the Rogue Valley is increasing, which demonstrates a deficit in the landscape's ability to recharge underground aquifers. In the 1950s and 1960, the typical well depth was 100 to 200 feet. In the 1990s, wells were usually 300 to 400 feet deep, occasionally extending to 800 or 1,000 feet deep (Dittmer, 1994). Increasing population demand and climate change will continue to diminish the ability of aquifers to fully recharge.

Residents and farmers rely on winter snowmelt to provide for their water needs during the dry summer growing season. The agricultural industry employs about 2500 people directly and 9000 indirectly. Josephine, Jackson, and Curry counties produce about $121 million in farm and ranch sales (Oregon Department of Agriculture/National Agriculture Statistics Service, 2013). Some impacts to local agriculture from climate change include disruptions in the timing and quantity of water flows, which will reduce already over appropriated surface water. Drought, which will affect ground water, soil health, and water demands. Water supplies will be limited resulting in limited use of hydro cooling due to lack of available water. In addition, warmer and wetter spring months may lead to conditions for pear blight, which would devastate the local agricultural economy. Warmer temperature will alter and modify the style of wine that the region can produce, altering the tourism of the region. Warmer temperatures will also change plant disease and pest timing and severity. Finally, high temperatures could reduce viability of pears and wine grapes, particularly Jackson County's pinot noir vineyards. Viable zones for wine grape production in southwest Oregon will likely shift toward the coast, northward, and upward in elevation, likely disappearing from the region by 2100 except in a narrow zone along the coast. Pollinators may be affected by climate change induced disease. Higher numbers of insects may lead to increases in pesticide use and reduced water quality. Monocultures will be more susceptible to disease. Growers that rely on single crops are likely to be more at risk financially than growers with a diverse array of crops. Horse farms are likely to face reduced pasturage options and higher feed costs due to rising costs for water (Myer, 2013).

A portion of all water that falls as rain and snow infiltrates into the subsurface soil and rock. Some water that infiltrates will remain in the shallow soil layer, where it will gradually move vertically and horizontally through the soil and subsurface material, water may infiltrate deeper, recharging groundwater aquifers. Water may travel long distances or remain in groundwater storage for long periods before returning to the surface or seeping into other water bodies, such as streams and the ocean (USGS, 2016). Infiltration of precipitation holds water in the basin longer than runoff, helping to maintain stream levels during the summer and recharge groundwater aquifers.

The goal of this research is to demonstrate the correlation between the addition of organic soil amendments into the soil, such as the addition of biochar, mulching, and cover crops and its influence on water infiltration. However, prior to attempting large-scale implementation, it is prudent to assess the feasibility of these techniques on a small scale. This feasibility study uses two types of rural land: timberland and oak savannah. The goal is to determine if the initial changes to the soil horizon are self-sustaining for the long term. Results will help make decisions on potential next steps to consider larger-scale implementation of these conservation techniques.

Research Questions

The question this research attempts to answer is, what is the most effective strategy to infiltrate precipitation into the soil and minimize runoff to retain moisture in the basin for summertime utilization? Studied techniques for water infiltration include biochar, mulching, and cover cropping which are used in this research project. It is the goal of this research to provide the Water Resource Department of Oregon, the Rogue Basin Partnership, Jackson Soil and Water Conservation District, Bureau of Land Management, and local landowners the information to implement effective strategies to infiltrate precipitation into the soil for utilization during the dry season.

Biochar is a solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment (International Biochar Initiative). Studies have proven biochar increases water infiltration and holding capacity (Abrol et al. 2016, Xiao, et al. 2016). 2 % biochar was found to significantly increase final infiltration rate by 1.7 times, and significantly reduce soil loss by 3.6 times, compared with a 0 % biochar control (Abrol et al., 2016). The average yields during a three-year study in Northern China showed a 10.2% and 14.2% increase in yields over the control plot, and the average water use efficiencies were 9.4% and 12.3% higher than in the control plot (Xiao, et al. 2016). These results indicate that biochar amendment could improve the physical and hydraulic status of semi-arid agricultural soils, thereby leading to an increase in plant available water.

Mulching or covering the soil surface with a layer of plant residue is an effective method of conserving water, because it reduces surface runoff and increases infiltration of water into the soil (Adekalu, et al. 2007). Adams (1966) found that mulching with rice straw significantly increased the infiltration of clay pan soils on sloping land. Bernett et al. (1967) observed a runoff of 17% of rainfall and 3.4 tons/ha of soil loss for rice straw mulched plots compared to 38% and 20.2 tons/ha for an unmulched plot. Lattanzi et al. (1974) showed that interill erosion was reduced by approximately 40% when wheat straw mulch was applied at a rate of 6 tons/ha and by an estimated 80% at a rate of 9.2 tons/ha. McCalla et al. (1963) found rice straw mulch cover to be more effective at increasing infiltration than incorporation of organic matter. Meyer et al. (1970) reported that 0.5 tons/ha of rice straw mulch can reduce soil loss by one-third of that with no mulch cover, and at 5 tons/ha could reduce soil loss by 95%. Khan et al. (1988) found mulching with rice straw to be more effective than using cover crop. Lal (1979) found mulching tilled soil with 4– 6 tons/ha of rice straw to be effective in reducing soil loss and runoff on slopes ranging from 1% to 15% and that the effectiveness of no-tillage in preventing runoff and erosion was comparable to applying 4–6 tons/ha of rice straw mulch (Adekalu, et al.

2007).

A cover crop may be defined as vegetation planted or managed to protect and improve soil, crops, or water quality. Generally, a cover crop is not harvested. It is frequently grown during a time between cash crops, although living mulch intercrops are also cover crops. It can be incorporated into the soil as a green manure or left as a mulch on the surface with no tillage management (Dabney, 1998). The presence of growing cover crops or residues can increase the hydrologic resistance of the soil surface and so slow down runoff. The roots of cover crops, and the fungal hyphae associated with them, help to bind the soil together. Thus, cover crops contribute to the stability of soil not only by increasing residue cover and reducing runoff, but also by rendering the soil less erodible (Dabney, 1998). These mechanisms of increasing infiltration, reducing runoff, and promoting soil stability allow cover crops to alter water retention and holding capacity of the landscapes they are planted on.

The implications of the results of this research could be used to alter the management of .87 million acres of Bureau of Land Management land in the Rogue Basin. The infiltration of water into the soil recharges groundwater which is used as the primary drinking source of over half the residents of the Rogue Basin. In addition, groundwater aquifers are used to irrigate thousands of acres of farm land within the basin. Finally, subsurface flow into streams provide water throughout the season which supports native fish populations.

Project Design

Working with a team of professionals from Bureau of Land Management, Jackson Soil and Water Conservation District, Southern Oregon University, Hamann Inc, Afternoon Zephyr Farm, Katalyst Inc. and Patton Environmental LLC to prepare the project design (see Appendix C for all project stakeholders). The team determined that two different site types would be sufficient for this feasibility study. The two sites are representative of rural land in the region: timberland and oak savannah which comprise 67% and 22% of land cover in the Rogue Basin (USGS 2001 National Land Cover Database) (see Appendix B for aerial photo of sites). Five test plots were constructed on each site, one as a control plot and the others as paired research plots with varying soil amendments (see Appendix B for amendment chart). Plot sizes were 18 feet by 36 feet and oriented vertically, with the long side perpendicular to slope.

At the Oak Savannah Site Plots 2a, 2b, 3a and 3b were broadcast seeded with half native and half nonnative fescue or grass seed mixes. The native seed mix was a Blue Wild Rye and Idaho Fescue. The non-native mix was a Tall Fescue/Dryland Orchard Grass. Plot 2a and 2b both were amended with composted Doug Fir bark, mixed with biochar, and fertilizer. Plot 2a was amended with a mix including a mycorrhizal component. Plot 2b was amended with a mix with no mycorrhizal component. Application method for both plots incorporate two berms or windrows on contour to physically hold water. Plots 3a and 3b were amended with chain-flailed wood, sourced from the nearby oak woodlands and top-dressed to 2 inches. Plot 3a not incorporate the chain-flailed wood into the soil, whereas Plot 3b was disked and incorporated into the soil to a depth of four inches.

Plots 4, 5 and 6 are at the BLM Forest Site Plot. Plot 6 is a control plot with no amendments. Plots 4a and 4b were amended with a top-dressed Doug Fir bark. Plot 4a has an additional amendment of biochar and fertilizer. Plot 4b has biochar with no fertilizer. Plots 5a and 5b are amended with chain-flailed wood, sourced from the dead material nearby. This material is cut to varying sizes and scattered across the plots. On 5a the material covers 25% of the plot surface, whereas on 5b, the material covers 75% of the plot surface.

Data

In the center of each plot are three Decagon EC-5 Soil Moisture sensors at depths of six inches, twelve to twenty inches, and thirty-six to forty inches. Soil moisture measurements were taken every fifteen minutes and stored in Campbell Scientific and Decagon Data Loggers. The data loggers were downloaded monthly on to a computer Microsoft Excel sheet for organization and analysis. In addition, soil temperature monitors were installed at each plot at a depth of six inches. The sites were both equipped with a HOBO Rain Gauge Data Logger by Onset for convenient and site specific meteorological information. The rain gauge tipping bucket logs each .01 inch tip and records its timing.

Methods:

The data has been graphed using Microsoft Excel. The graphs represent each sites soil moisture data by soil moisture depth, which compares all of the six inch, twenty inch, and forty inch soil moisture data points for each site (Kimmel and Wasson). The soil moisture is graphed with precipitation data collected at each site. Negative data points and outliers have been removed before further analysis. In addition, using IBM SPSS Statistics software, the descriptive statistics for each soil moisture dataset was analyzed and presented with the corresponding graph. Descriptive statistics include range, mean, minimum, maximum, standard deviation, variance, skewness, and kurtosis (see appendices). Finally, a one-way Analysis of variance (ANOVA) test was used to analyze the difference between the control plots at each site compared to the treated plots at each sites soil depth.

Results and Discussion:

The results of this study are ongoing, however, preliminary analysis do show statistically significant differences between the control and treated plots. From the ANOVA test we can state at every depth and treatment plot that there is a statistically significant difference between the control and treated plots. We can reject the null hypothesis and state that the treatments applied to the soil are creating a difference on soil moisture retention. At the Kimmel site, the Windrow treatments are consistently showing higher mean soil moisture than the mulched sites and control. This suggest the Windrow treatments are better equipped to hold a higher soil moisture than the mulched treatment plots. At the Wasson site there is less obvious conclusions. However, preliminary data is showing the Mulched with Biochar and No Fertilizer holding the highest soil moisture.

Conclusions:

At the Kimmel site, there is a large response difference between how the six inch depth responds to precipitation events compared to the deeper soil moisture depths. The Control Plot had the lowest range, highest minimum and highest mean at both the twenty inch and thirty-six inch depth. 2B Windrow with No Mycorrhizal treatment had the highest maximum soil moisture at both the twenty inch and thirty six inch depth. Unfortunately, 3A had the lowest maximum at both the twenty inch and thirty-six inch depth levels. This information, suggest that the lower soil horizons (twenty and thirty-six inch depth) are compositionally more similar than the higher soil depth (six inches). In addition, the thirty-six inch soil depth showed the most variation in saturation and drying events, with intensive peaks during and following precipitation events and low valleys between precipitation events, differences averaging fifteen to twenty percent soil saturation.

At the Wasson Site similar to the Kimmel site, we see a correlation between the two deeper depths (twenty inch and forty inch) response to precipitation events compared to how the highest depth (six inch) responds. 4B Mulched with Biochar and No Fertilizer has the highest mean and highest minimum at both the twenty inch and forty inch depth. 4A Mulched with Biochar and Fertilizer interestingly has the lowest Minimum during this same time period. 5A Wood Coverage at 25% and 5B Wood Coverage at 75%, both have the lowest range for the twenty and forty inch depth. The Control Plot is possibly the most interesting at the Wasson Site. The Control Plot has the highest range at the six inch and forty inch depth. In addition, it has the lowest maximum soil moisture saturation at the twenty inch depth, but then jumps to having the highest soil moisture saturation at the forty inch depth.

While the data analysis for this project is ongoing and the results are preliminary. From the fall of 2016 to the winter of 2017, there are some interesting trends occurring. From the current research we can infer that the deeper soil depths are compositionally more similar then the highest soil horizon. This information suggest that surface treatments can alter the highest soil horizons as compared to deeper layers. More data analysis will be needed in the future, especially over the spring and summer of 2017 to watch trends in soil dehydrating. From the collection of this data, stakeholders at the BLM, Jackson County Soil and Water Commission and the Rogue Basin Partnership will be able to infer more information about the possibility of conserving and retaining water in the soil horizon for summer utilization.

Appendix A: Illustrations

Figure 1: Aerial Photo of Sites; Left: Kimmel Site (Agricultural/Oak Savanna); Right: Wasson Site (Forested)

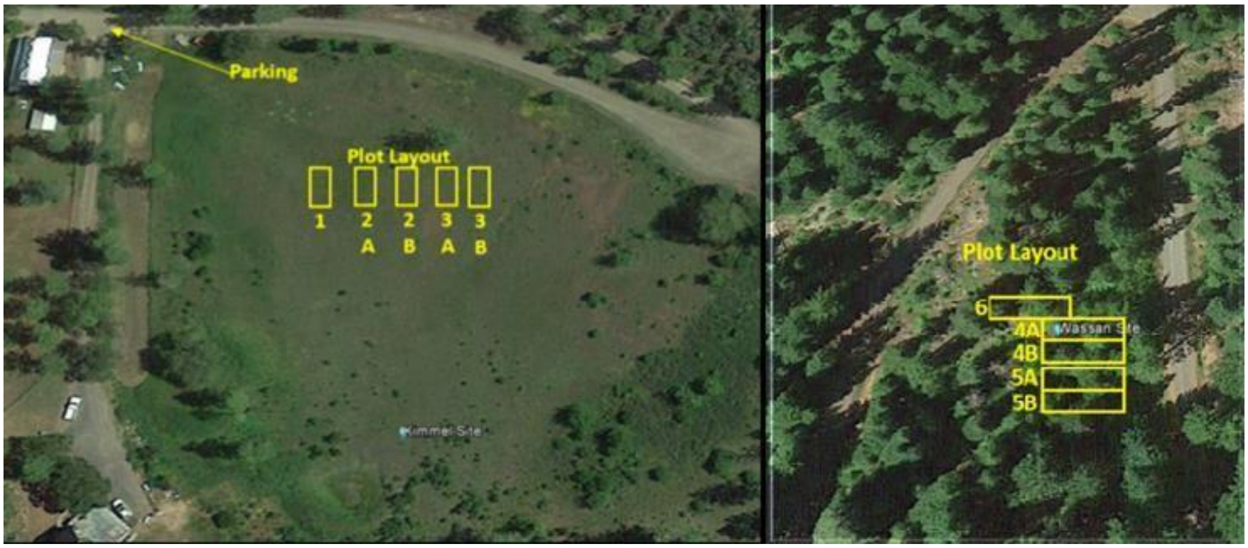

Figure 2: Plot Amendment Chart

Feasibility Study to Assess the Potential Water Conservation in Upland Soils by Increasing Organic Content	Oak Savannah (Kimmel)					Forest (BLM-Wasson)				
Formula – Wood Type/Amendment/Application	Control	Paired Plots (chem variable)		Paired Plots (mech variable)		Paired Plots (mech variable)		Paired Plots (chem variable)		Control
	Plot #1	**2 A**	**2 B**	**3 A**	**3 B**	**4 A**	**4 B**	**5 A**	**5 B**	**6**
Wood Type:										
Decomposed Wood Waste - Compost/Mulch		x	x							
Douglas Fir Bark (DF) (3/8th's minus 1 yard per plot) (by Jason, Ground Control						x	x			
Local limbs and logs chain sawed into large pieces								x	x	
Chain flailed wood (top dressing – 2 inches deep)				x	x					
Amendment Type:										
Fescue seed –upper ½ native mix, lower ½ non-native mix		x	x	x	x					
Bio char + fertilizer + special grass mycorrhizal		x								
Bio char + fertilizer with no mycorrhizal			x							
Biochar+ fertilizer (not chicken)						x				
Application Method:										
Windrow (centered in plots) 6 in high, 12 in wide		x	x							
Topdress 2 inches, Disc in to shallow soil					x					
Topdress 2 inches, no disc				x		x	x			
Lop & scatter (cover 75% of plot surface)									x	
Lop & scatter (cover 25% of plot surface)								x		

Appendix B: Stakeholders

- Water Resources Department (WRD) Funding for feasibility study, grant administration, technical support
- Rogue Basin Partnership (RBP) - Grant Administration, contracts, landowner agreements
- Patton Environmental LLC - Project Management, Design, Data Analysis, Reporting
- Bureau of Land Management (BLM) - Site, Design, Soil and Vegetation Assessment, Data Analysis, Graphics, Outreach, Peer Review
- Jackson Soil & Water Conservation District (JSWCD) - Design, Soil Moisture Monitoring, Data Analysis, Outreach
- Southern Oregon University (SOU) - Design, Student Interns, Site Monitoring, Data Analysis, Outreach, Peer Review
- Hamann Inc. - Site, Design, Plot Construction, Site Monitoring
- Afternoon Zephyr Farm - Design, Site Monitoring, Data Analysis
- Katalyst Inc. - Design, Peer Review
- Seven Basins and Rogue River Watershed Councils - Volunteer Monitoring, Outreach

Appendix C: Descriptive Statistics

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
MulchedwithBiocharFertilizer6	18039	1.18	-.44	.74	.4522	.24931	.062
WoodCoverage756	17543	.13	.16	.28	.2370	.02536	.001
MulchedwithBiocharNoFertilizer6	8056	.09	.20	.28	.2350	.01721	.000
WoodCoverage256	17121	.06	.20	.25	.2320	.01215	.000
Control6	18039	.77	-.47	.30	-.0348	.27725	.077
Valid N (listwise)	8056						

Figure 3: Wasson 6” Descriptive Statistics between October 14, 2016 – April 20, 2017

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
MulchedBiocharNoFertilizer20	3690	.12	.30	.42	.3379	.01983	.000
WoodCoverage7520	3640	.09	.30	.39	.3371	.01875	.000
MulchedBiocharFertilizer20	16863	.09	.20	.30	.2603	.01133	.000
Control20	4918	.04	.23	.27	.2505	.00713	.000
WoodCoverage2520	17009	.05	.22	.27	.2441	.00623	.000
Valid N (listwise)	3640						

Figure 4: Wasson 20” Descriptive Statistics between October 14, 2016 – April 20, 2017

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
MulchedBiocharNoFertilizer40	2369	.07	.29	.36	.3260	.01283	.000
WoodCoverage2540	4232	.08	.24	.32	.2823	.01327	.000
MulchedBiocharFertilizer40	4232	.20	.09	.28	.2216	.04891	.002
Control40	4232	.32	.10	.42	.2132	.05825	.003
WoodCoverage7540	4232	.08	.13	.21	.1533	.01811	.000
Valid N (listwise)	2369						

Figure 5: Wasson 40” Descriptive Statistics between October 14, 2016 – April 20, 2017

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
WindrowNoMycorrhizal	1927	.23	.38	.61	.5010	.09870	.010
Control6	7394	.25	.22	.47	.3763	.04278	.002
WindrowWithMycorrhizal	7394	.11	.29	.40	.3281	.02423	.001
MulchedDisked6	7394	.05	.25	.30	.2697	.00954	.000
MulchedandNotDisked6	9394	.68	-.37	.31	.1322	.26424	.070
Valid N (listwise)	1927						

Figure 6: Kimmel 6" Descriptive Statistics between October 14, 2016 – April 20, 2017

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
WindrowMycorrhizal20	8097	.14	.57	.71	.6419	.03320	.001
WindrowNoMycorrhizal20	6832	.13	.44	.56	.5277	.03384	.001
Control20	7394	.02	.51	.53	.5204	.00486	.000
MulchedandDisked20	7394	.04	.47	.51	.4896	.01091	.000
MulchedandNotDisked20	7394	.14	.31	.45	.3836	.03163	.001
Valid N (listwise)	6832						

Figure 7: Kimmel 20" Descriptive Statistics between October 14, 2016 – April 20, 2017

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Control36	13744	.19	.31	.50	.4558	.05896	.003
WindrowNoMycorrhizal36	7213	.32	.24	.55	.4470	.11385	.013
MulchedandNotDisked36	13744	.26	.25	.51	.3875	.06624	.004
MulchedDisked36	13744	.37	.15	.52	.3750	.15419	.024
WindrowMycorrhizal36	13094	.48	.01	.49	.3390	.08568	.007
Valid N (listwise)	7213						

Figure 8: Kimmel 40" Descriptive Statistics between October 14, 2016 – April 20, 2017

Appendix D: Soil Moisture Graphs

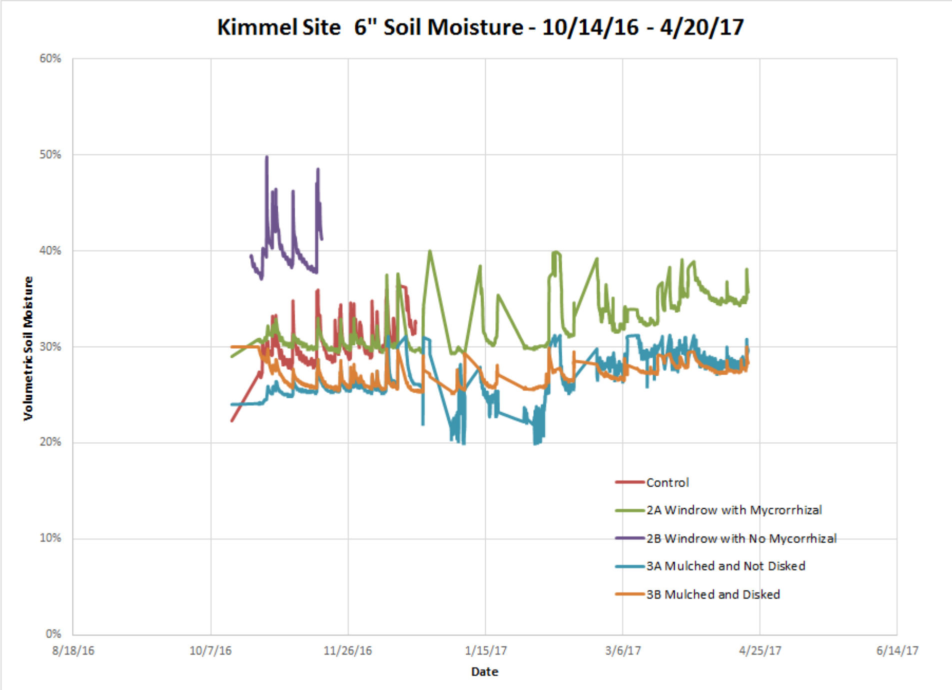

Figure 9: Soil Moisture and Precipitation Graph of Kimmel Site 6”

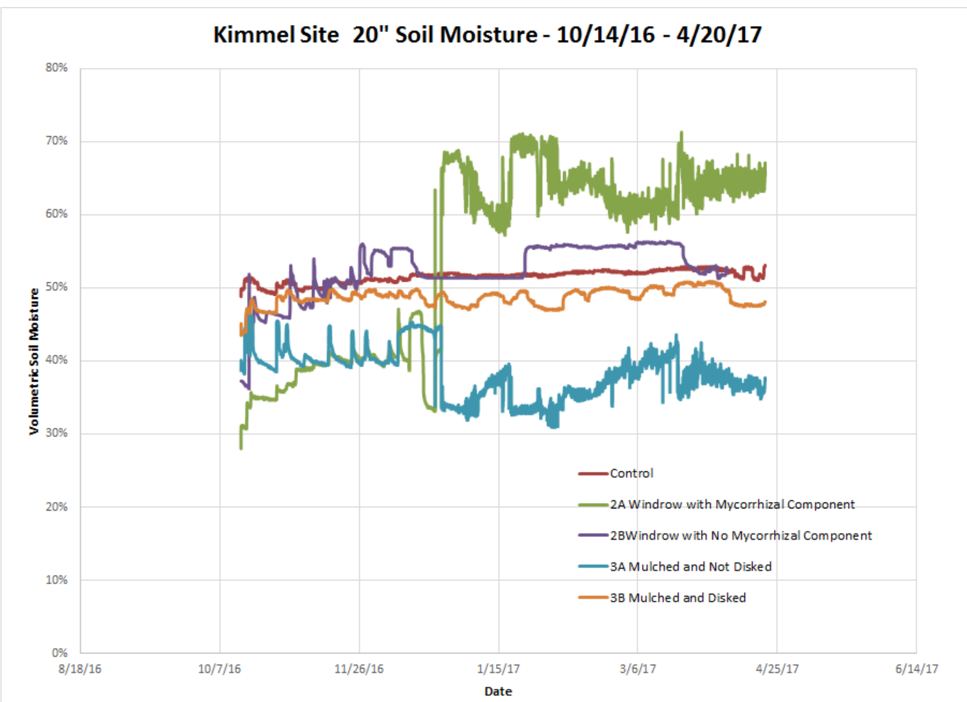

Figure 10: Soil Moisture and Precipitation Graph of Kimmel Site 20”

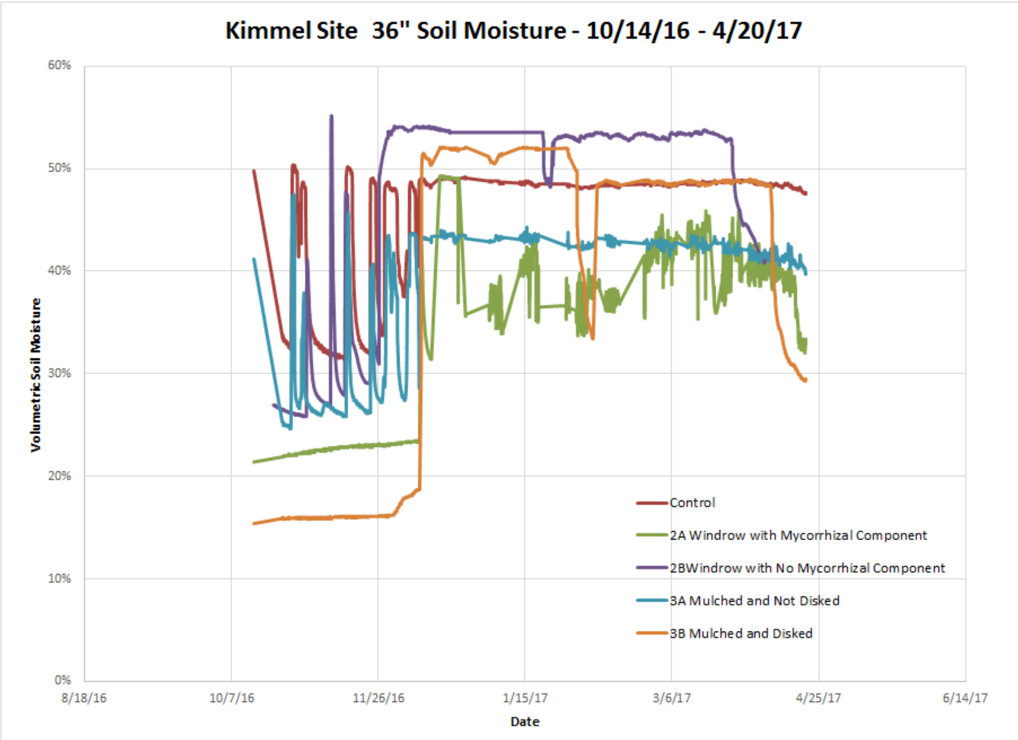

Figure 11: Soil Moisture and Precipitation Graph of Kimmel Site 36"

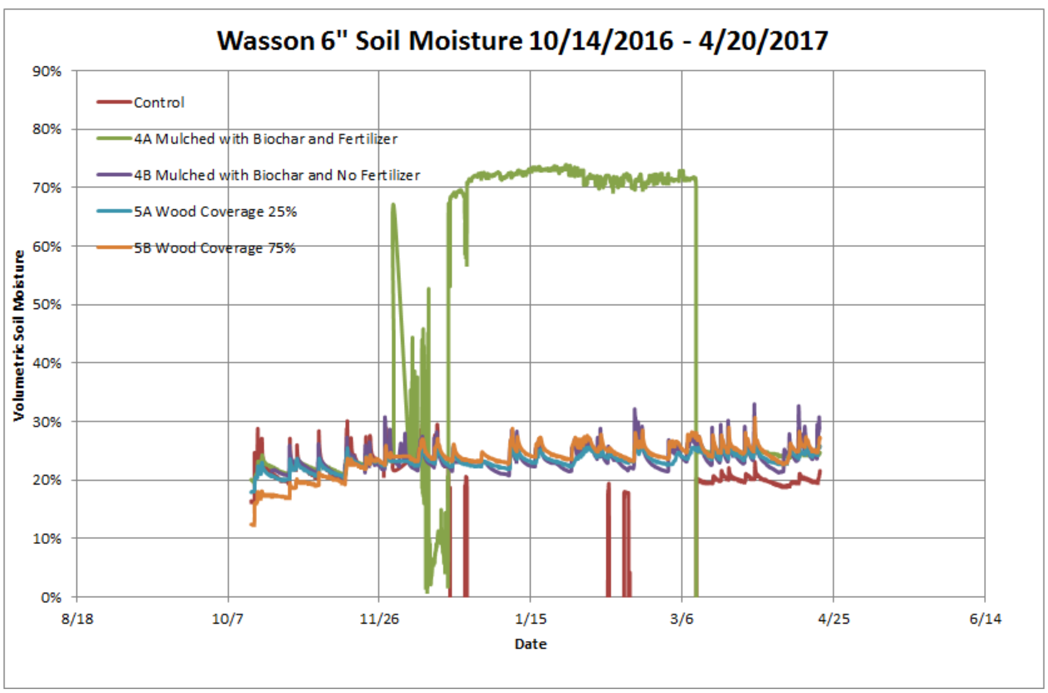

Figure 12: Soil Moisture and Precipitation Graph of Wasson Site 6"

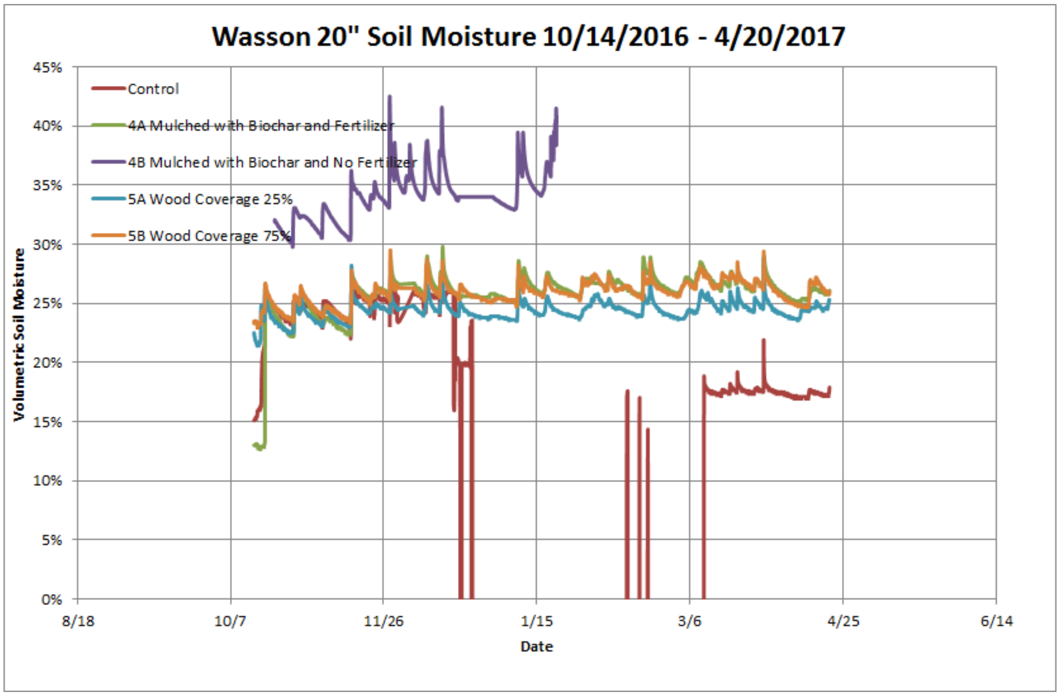

Figure 13: Soil Moisture and Precipitation Graph of Wasson Site 20”

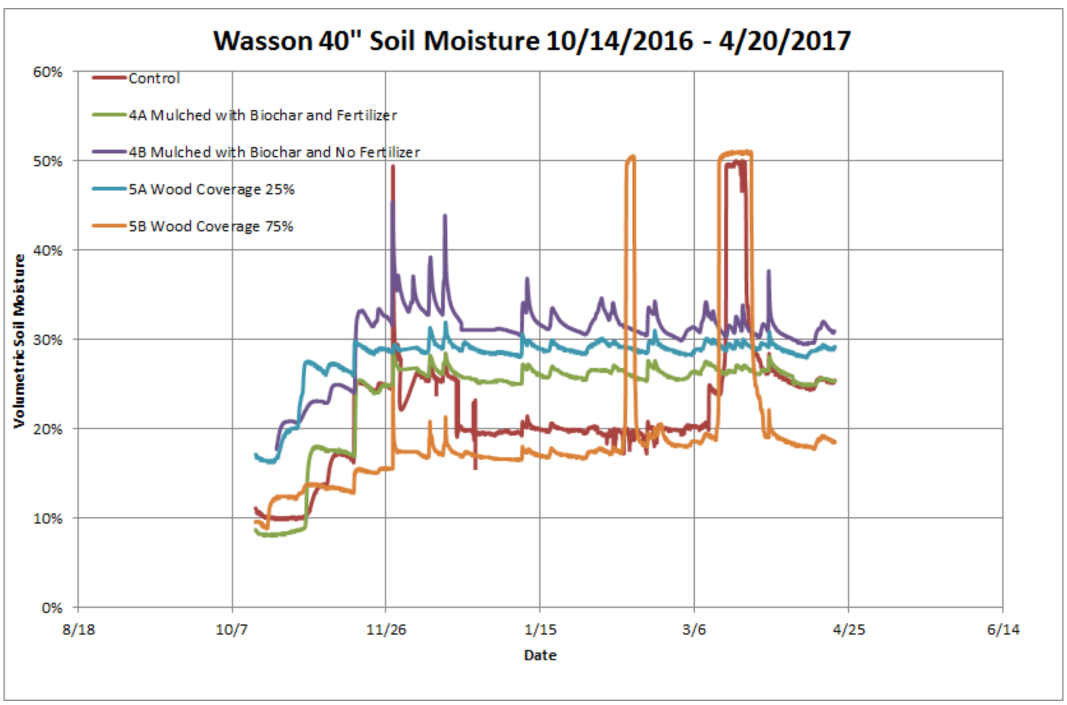

Figure 14: Soil Moisture and Precipitation Graph of Wasson Site 40”

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