THE POTENTIAL OF LANDSCAPE SCALE TREATMENTS TO REDUCE SUBLIMATION LOSSES OF CRITICAL WATER SUPPLY SNOWPACK IN THE WESTERN UNITED STATES

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ABSTRACT

A variety of treatments were tested for their effectiveness at limiting sublimation losses from snowpack. Treatments tested included vertical compaction, spraying the snowpack with a coating of vegetable oil, and applying a layer of chipped Ponderosa Pines slash biomass over the top of the snowpack. In meadow areas, untreated snowpack ablated at a rate of 0.66 centimeters of snow water equivalent (SWE) per day, while snowpack covered with a thick blanket of biomass ablated at a rate of 0.10 centimeters of SWE per day. Further, at the end of the data collection period, the control had lost 100% of its original SWE, while the biomass treated snowpack only lost 22% of its original SWE. In areas with a dense forest canopy, untreated snowpack ablated at a rate of 0.53 centimeters of SWE per day, and the snowpack treated with a thick biomass blanket averaged a loss of 0.20 centimeters of SWE per day. It was determined that a thick layer of biomass (about seven to ten centimeters in depth) would help reduce sublimation losses of snowpack in both meadow and canopied areas. A cost analysis was performed to determine the price of application of the thick biomass blanket, and it was determined that one application would cost roughly $365 per 4,047 square meters (1 acre). This high cost of application poses a real challenge to the feasibility of implementing this treatment to reduce sublimation losses at landscape scales.

(KEYWORDS: snowpack, sublimation, water supply, snow preservation treatment, biomass blanket)

INTRODUCTION

Snowpack, with respect to both depth and duration, plays an important role in shaping the climate and biota of Earth, as well as impacting the way humans live. Alterations to snowpack result in changes to precipitation and weather patterns. Intimately related to both the weather and the direct impacts of snow on the ground are changes in vegetation and, consequently, wildlife. Additionally, snowpack plays a vital role in regional and local water supplies and water storage for human populations.

In the state of Arizona, the Colorado River and the Salt River Drainage Basin are primarily fed by snowpack and provide nearly half of Arizona's water (Arizona Department of Water Resources). Due to the arid climate of Arizona, approximately 80% of the snow water equivalent in the snowpack never makes it into surface water runoff (Ffolliott and Baker, 2000). Finding a treatment for snowpack which could reduce sublimation losses would be beneficial for watersheds which rely on snowpack as a large part of their water supply source.

METHODOLOGY

Small scale study plots were built to test the potential of different treatments at limiting the sublimation losses from snowpacks. Four separate study plots were constructed; one study plot in an open meadow area, one under a significant forest canopy, and two under removable roof structures, so that individual storm events could be investigated. Each study plot was 2.75 meters x 2.75 meters, containing four 1.22 meters x 1.22 meters subplots. Three subplots were treated and one was left untreated as a control.

Although data collection was set to begin in mid-January, the first significant storm event of the winter 2010-11 data collection season did not occur until mid-February. Treatments were applied to the meadow, canopy and one roof plot after the first storm event, and snow water equivalent (SWE) monitoring ensued. After the second major storm event, treatments were reapplied to the meadow and canopy plots, and the second roof plot was treated and covered. Snow water equivalent monitoring ended on March 11th, when most of the snow had been lost to melting and sublimation.

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The SWE measurements were taken using a sampling tube and a microbalance. The sampling tube was used to extract snow from the study plot. The extracted snow was then put into lab beakers, where they were taken to the Environmental Lab on the Northern Arizona University campus and weighed. The SWE was calculated using the weight of the snow, the density of water, and the measured surface area of the sampling tube. The resulting value was the depth of water equivalent contained in the snowpack.

RESULTS

The two roof structures captured one storm event each. The results showed a stronger correlation between where the subplot was located (under north end of roof structure or south) than any correlation between the treatment applied and the rate of SWE loss. This indicated that the results had been affected by sunlight hitting the southern end of the plots, and rendered the data unusable for analysis.

The canopy and meadow plots provided better indications of how well treatments performed with respect to the control. Both plots captured two storm events; however, only the data after the last storm event was used because the storms were close together and the time period between the first and second storms did not provide enough SWE data points to draw conclusions.

In the open meadow plot, only the treatment of biomass retained snow better than the control. Although there was far more variance in the biomass data than in the control data, the slope of the best fit line clearly indicates that biomass slowed snow loss significantly.

Figure 1 below shows the plot of the SWE measurements under the biomass blanket over time versus the plot of the control SWE measurements over time. The best fit line is also shown.

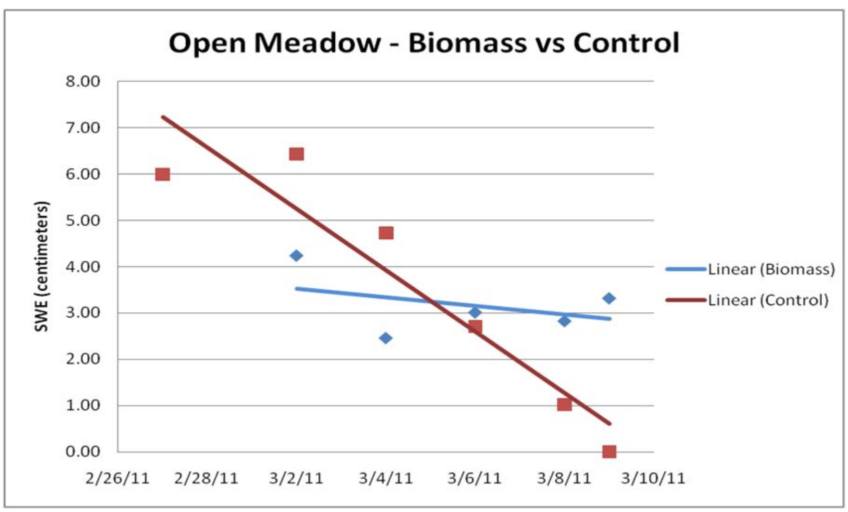

Figure 1: SWE versus time for the open meadow study plot from February 27th to March 9th, 2011

Table 1: Slope and R^2 values of the regression lines from Figure 1.

	Slope (cm SWE/day)	R^2 Value
Control	-0.66	0.89
Biomass	-0.10	0.16

As can be seen in the above table, the snow in the thick biomass subplot ablated at a rate of 0.10 centimeters of SWE per day, while the control shows an average loss of 0.66 centimeters of SWE per day. The R^2 values for the thick biomass and control subplots were 0.16 and 0.89, respectively. The R^2 value for the control shows a strong correlation in the data, while the R^2 for the thick biomass subplot shows a fairly weak correlation.

The weak correlation is believed to be due to the “mounding” of the snow under the thick biomass layer. The snow had high points and low points under the biomass layer. This made it very difficult to sample at an average location representing the entire subplot, which is why the data seems to vary a bit, causing a low correlation between the regression line and the actual data. However, it is fairly obvious by looking at the raw data, that the biomass limited the losses of the snowpack simply because a significant amount of SWE was still under the biomass on the last day of data collection. At the end of the data collection period, the control had lost 100% of its original SWE, while the thick biomass subplot had only lost about 22% of its original SWE.

The canopy results were similar to the meadow with the biomass treatment performing best. The correlation in results was better than the open meadow, although the biomass treatment again had more variance than the control.

Figure 2 below shows the plot of the biomass SWE measurements over time versus the plot of the control SWE measurements over time. The best fit line is also shown on the plot.

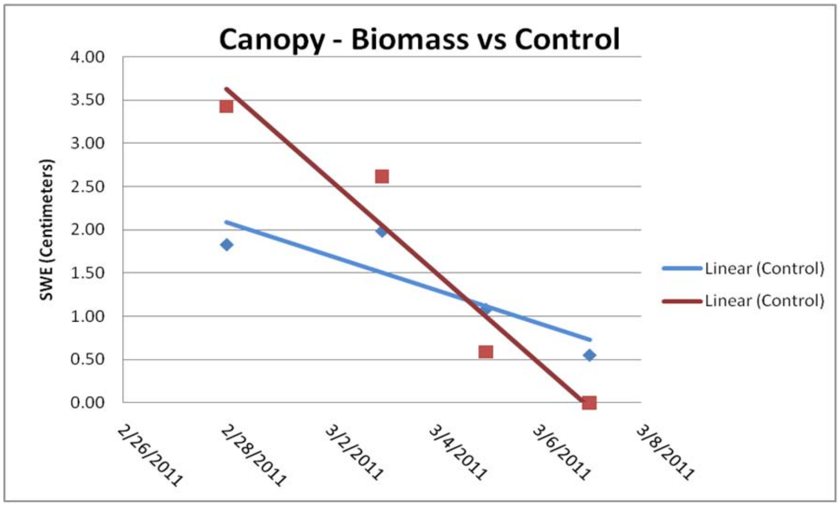

Figure 2: SWE versus time for the canopy study plot from February 28th to March 7th, 2011

Table 2: Slope and R^2 values of the trend lines from Figure 2.

	Slope (cm SWE/day)	R^2 Value
Control	-0.53	0.93
Thick Biomass	-0.19	0.75

The slopes of the regression lines indicate that the average rate of SWE loss was 0.53 centimeters on the control subplot and 0.19 centimeters on the thick biomass subplot. The R^2 values for the thick biomass and control subplots were 0.75 and 0.93. Each of these values shows a fairly strong correlation between the regression line and the data the line represents. Further, at the end of the data collection period, the control had lost 100% of its original SWE, while the thick biomass subplot had only lost about 70% of its original SWE.

COST ANALYSIS

It is proposed that slash piles left behind from forest thinning practices, which are usually burned, instead be chipped or shredded and then applied to the snowpack as a treatment against sublimation losses. To perform this cost analysis it was assumed that a fuels crew, which typically piles up and burns the forest slash of limbs and branches, would not resulting in any additional costs, as their roles are going to be in place, anyway. It was also assumed that the limbs and branches will be chipped in an area of the forest which will minimize the transport distance to the site of application. The cost analysis included the operation and maintenance cost of a tractor, wood chipper and woodchip spreader. Based on these assumptions, it was determined that applying a seven to ten centimeter layer of biomass over the top of the snowpack would cost $365 per 4,047 square meters of treated area.

CONCLUSIONS

The treatments applied to the snowpack were aimed at targeting sublimation losses; consequently, an important priority in the design of the experiment was to isolate the losses incurred by sublimation from other losses, such as melting. The primary driving forces behind sublimation are wind and low humidity. When these two phenomena are coupled with temperatures below freezing, an ideal environment for monitoring only sublimation losses is obtained. If temperatures are above freezing, sublimation still occurs, but it becomes difficult to differentiate between sublimation losses and melt losses.

During much of the data collection period, the weather conditions did not allow for differentiation between melt losses and sublimation losses. Daytime highs during the data collection period were always above freezing, and often near 12 to 15 degrees Celsius. Thus, the snow which was treated and sampled, while still undergoing loss to sublimation, was also losing SWE to melt. The key assumption made was that the snow kept on the ground for a longer period of time is a result of the applied treatment restricting snow losses. These losses include both sublimation and melting.

The canopy and meadow results both clearly showed that a thick layer of biomass (about seven to ten centimeters in thickness) delayed the snowpack losses when compared to the control and the other two treatments. At least part of the reason why a thick biomass blanket is effective at retaining snowpack is because of its ability to reduce the sublimation losses.

The application of seven to ten centimeters of biomass would be a very expensive treatment. The cost analysis showed that the cost of application of the biomass blanket would be in the range of about $365 per 4,047 square meters. Based on the initial estimates, it seems unlikely that this treatment would be cost effective to implement at a landscape scale. It should be noted, though, that biomass blanketing does have the potential to preserve 60% to 80% of a snowpack until the onset of the snowmelt season, which in arid climates is significant. In a snowpack with 15 centimeters of SWE, that’s 9 to 12 centimeters more water than if the same area was left untreated. When looking at an area of 4,047 square meters, that amounts to approximately $1000.00 per 1,234 cubic meters of additional water. If at some point the treatment were to be considered cost effective, it should be implemented in a meadow area. Not only have biomass blanket treatments proved more effective in meadows, but meadow areas also receive more snowfall on the ground than forest canopy areas, and the machinery utilized to spread the blanket will be easier to operate in an open area. It is recommended that further research be conducted to evaluate the performance of biomass and other sublimation loss mitigating treatments.

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