7.4 SPATIAL AND TEMPORAL VARIABILITY OF SOIL MOISTURE AND TEMPERATURE IN RESPONSE TO FIRE IN A MONTANE PONDEROSA PINE FOREST

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1. INTRODUCTION

Wildfires are extremely powerful events that may claim lives, homes, and thousands of acres of forests in a span of only a few hours. The impact of forest fires is a topic that is currently of great interest in many areas of the world, including the western United States. Today's environment has faced population growth, increased land use, and a greater demand for forest-based products. Therefore, suppression of wildfires has become a necessary tool for human survival in the arid west (Ahlgren 1974, Bailey and Covington 2002). Subsequently, fuel density has increased immensely in many semiarid ponderosa pine forests (Johansen et al. 2001), posing a risk of high-intensity wildfires in large portions of the western United States (Beeson et al. 2001). This risk becomes even more threatening along the front range of Colorado, where the human-wildland interface lies within this high-risk zone (Benavides-Solorio and MacDonald 2001). The increased risk of wildfire in these areas may be severely heightened with climate change, particularly under the extreme circumstances predicted by many current climate models (Beeson et al. 2001). Both intense droughts and large periodic storms have been projected for the 21st century, causing an increased risk of wildfire paired with amplified post-fire runoff and erosion (Beeson et al. 2001). In order to implement the best management techniques for fire prevention and mitigation, as well as post-fire rehabilitation and remediation, a thorough understanding of the impacts of fire on the forest microclimate is essential. Without a fundamental awareness of the implications of forest fire, human lives, homes, and land in the Colorado Front Range may soon be in grave danger.

The following research investigated the consequences of the 2000 Hi Meadow fire on the forest microclimate outside of Bailey, Colorado. In particular, this research focused on the impacts of fire upon soil moisture and temperature in a semiarid ponderosa pine forest in the foothills of Colorado. Soil moisture and temperature were measured continuously for one year in both a burned and unburned area of forest in order to decipher the impacts of forest fire on the temporal variability of soil characteristics. Soil moisture and temperature were also measured weekly over set intervals in each site to determine the effects of fire on spatial variability. Understanding how fire affects these basic soil properties over space and time was the main goal of this research.

Measurements of forest characteristics were made in order to establish which factors had the largest role in controlling soil characteristics in each site. Factors such as Leaf Area Index (LAI), percentage of visible sky, slope, and litter depth were examined and the magnitude of their effects was analyzed. The influence of a litter layer was further tested by removing a section of litter from the unburned site and installing it in a plot in the burned site. Differences between soil characteristics in the control and experimental plots after the litter exchange would solely be due to the addition/removal of the litter layer.

2. RESULTS

Moisture measurements from continuous datalogger recordings were averaged over a one year time period. The average yearly soil moisture was 6.77% by volume in the unburned site and 4.29% by volume in the burned site. Although the average soil moisture was slightly higher in the unburned site, moisture differences between the two sites were within the natural range of variability for the probes. This suggests that the fire that occurred in 2000 is not currently having a large impact on long term soil moisture levels. This would furthermore suggest that the interception of precipitation by the canopy and the use of moisture by tree roots in the unburned site are as effective in reducing soil moisture levels as the process of evaporation in the burned site.

To test the spatial variability of soil moisture, a Hydrosense was used to measure moisture content at 36 points within each site on a weekly basis (during the growing season when the ground was thawed). Maps of daily moisture values were created for each site (Figure 1 and 2) in order to show differences in moisture trends between sites. When spatial soil moisture averages were calculated, the soil moisture trends were actually quite similar for the two sites. The overall moisture average (all 36 points averaged over all days sampled) for the unburned site was 8.32% by volume (sd = 6.87%), while the overall average for the burned grid was nearly identical at 8.15% by volume (sd = 6.77%). One point in the burned site tended to always have a much higher soil moisture

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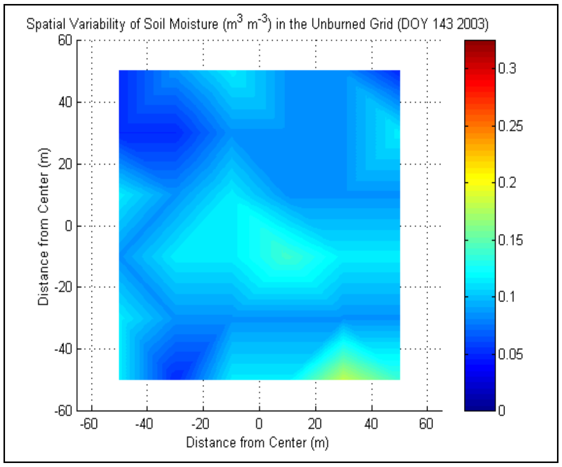

Figure 1. Spatial variability of soil moisture in the unburned site on julian day 143, year 2003. The colorbar on the right shows soil moisture content measured in $m^3\,m^{-3}$.

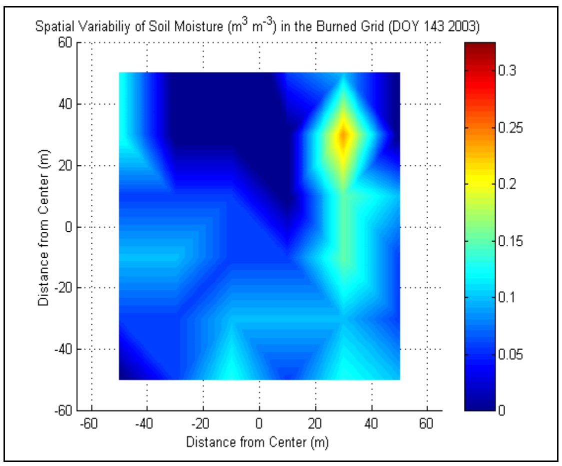

Figure 2. Spatial variability of soil moisture in the burned site on julian day 143, year 2003. The colorbar on the right shows soil moisture content measured in $m^3\,m^{-3}$.

content than the other 35 points. When this outlier was removed, the overall moisture average of the burned sit dropped to 7.77%.These results do not suggest that soil moisture averages are different between the two sites, nor that the unburned site is continuously moisture than the burned.

Datalogger temperature readings were averaged for both sites over the course of the growing season (when ground temperatures were above 0ºC). The average temperature was 8.50ºC (sd = 5.60ºC) in the unburned site and 12.77ºC (sd = 9.06ºC) in the burned site. Average temperatures are both lower and less variable in the unburned site, indicating that the fire in 2000 made a large impact on soil temperatures. The presence of a forest canopy, as well as the presence of a litter layer, protects the soil from incoming solar radiation. This results in cooler growing season temperatures at the ground level, thereby reducing evaporation from the soil.

This large difference in temperature between the two sites initiated an experiment to test the importance of the presence of a litter layer on soil moisture and temperature. Two plots were erected in each site with moisture and temperature probes installed in each plot. After a two month calibration period, the two plots in each site were split into a control and experimental plot. The experimental plot in the unburned site had the litter layer removed, while the experimental plot in the burned site had a litter layer added. Differences in readings between the two plots would be solely due to the addition/removal of the litter layer.

The control and experimental plots in the unburned site were compared before and after treatment to determine the effect of litter removal on soil moisture (Figure 3). Statistically, experimental plot A had a volumetric soil moisture of 9.94% (sd = 4.62%) before the removal of the litter layer and 5.77% (sd = 4.38%) after the litter removal. Due to apparent changes in weather and physical conditions during the before and after portion of the study, we must compare these changes to the changes in the control plot. Control plot B had a mean volumetric soil moisture of 8.34% (sd = 5.13%) before day 198 and 6.45% (sd = 4.67%) after day 198. By comparison, the average volumetric soil moisture after treatment was reduced nearly twice as much in the experimental plot. The change in variability (standard deviation) was relatively consistent between the two plots. This suggests that the removal of the protective litter layer from the soil may contribute to lower soil moisture levels.

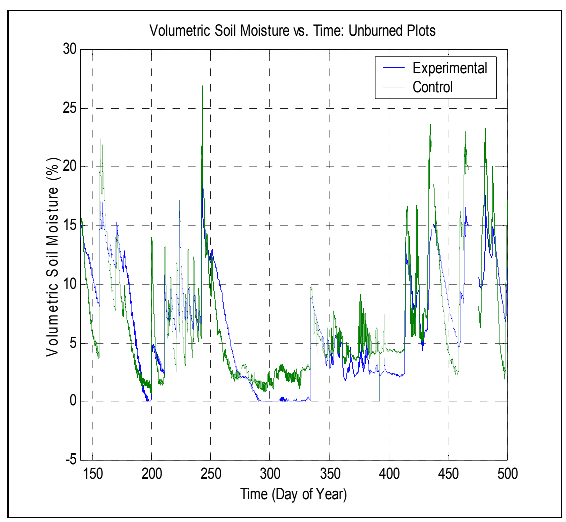

Figure 3. Volumetric soil moisture (%) vs. time in the unburned plots. Measurements have been adjusted to account for innate differences between the probes. Litter was removed from the experimental plot on day 198.

In the burned site, a layer of litter was added to the experimental plot on day 198. It is evident that shortly after the addition of the litter layer on the experimental plot (plot A), diurnal fluctuations in soil moisture levels are greatly dampened (Figure 4). It can also be noticed that soil moisture in the experimental plot tends to be consistently higher than the control plot after the treatment was initiated. Statistically, the mean volumetric soil moisture in the experimental plot was 8.96% (sd = 5.43%) before treatment and 5.68% (sd = 3.55%). Control plot B had a mean soil moisture of 6.22% (sd = 3.15%) before treatment and 4.37% (sd = 4.06%) after treatment. The statistical analysis confirmed visual expectation and suggested a post-treatment decrease in variability in the experimental plot, while the control plots shows increased variability after the initiation of treatment. Although the experimental plot statistically shows a greater overall decrease in volumetric soil moisture in response to treatment, this statistical analysis may be deceiving. The mean soil moisture of the control plot before treatment (8.96%) may be slightly skewed due to variability. The equation of the line has been forced to match that of the control plot, yet the mean soil moisture is almost 2.5% higher. From the graph, it is apparent that the experimental plot, with the litter treatment, is consistently wetter than the experimental plot, regardless of the change in calculated means.

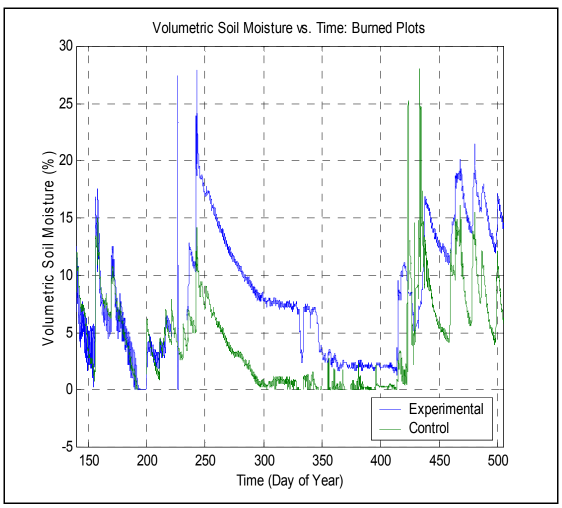

Figure 4. Volumetric soil moisture (%) vs. time in the burned plots. Measurements have been adjusted to account for innate differences between the probes. Litter was added to the experimental plot on day 198.

3. CONCLUSION

Although it is evident that the Hi Meadow fire did impact soil characteristics at the burned site, measured differences were, in most cases, much less than expected. This may be due to the length of time that had elapsed between the fire and the onset of the study. Additional differences may be due to the lack of storm days during the period of study, or simply to instrumentation or measurement errors.

Changes in soil moisture were not as straightforward as changes in temperature. Differences in both soil moisture and soil moisture variability were much less than expected between the two sites. It was expected that soil moisture in the unburned site would be much higher due to the lower temperatures provided by the shelter of the canopy and the litter layer. The difference in moisture between the two sites was negligible, indicating that canopy precipitation interception may be an important factor in this ecosystem. Again, these results may provide insight as to how management practices should be developed to aid in post-fire recovery.

4. REFERENCES

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