IMPACT OF RAINFALL ON THE MOISTURE CONTENT OF LARGE WOODY FUELS

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Abstract—This unreplicated case study evaluates the impact of rainfall on large woody fuels over time. We know that one rainfall event may decrease the Keetch-Byram Drought Index, but this study shows no real increase in fuel moisture in 1,000-hour fuels after just one rainfall. Several rain events over time are required for the moisture content of large woody fuels to increase thereby impacting fire behavior.

INTRODUCTION

A prolonged drought in the Southeastern United States increased the severity of southern pine beetles (*Dendroctonus frontalis*) throughout the region. Since 2001, South Carolina alone has detected over 92,000 beetle-killed spots and the death of approximately 25.5 million trees. After these attacks as dead trees fall, a particular concern is heavy fuel loading and how to predict when large fuels will ignite. Fire behavior models typically don't account for these fuels, but when ignited, logs can increase fire intensity and/or duration and become a problem for smoke management (Haywood and others 2004).

Land managers are commonly faced with prescribed fires that have higher intensities than expected after prolonged droughts. One reason for this discrepancy is that land managers are using the Keetch-Byram Drought Index (KBDI) alone to estimate fire behavior. The KBDI is part of the National Fire Danger Rating System and is the most widely used drought index for the fire danger rating. The KBDI was developed by John Keetch and George Byram to look at the effects of long-term drying on litter and duff and subsequently, on fire activity. The index ranges from zero to 800 with zero being saturated and 800 the worst drought condition. The index measure is in hundredths of an inch and is based on a measurement of 8 inches of available moisture in the upper soil layers. The available moisture can be used by vegetation for evapotranspiration. The index indicates deficit inches of available water in the soil. A KBDI of 250 means that there is a deficit of 2.5 inches of ground water available to the vegetation (Melton 1989). During a long dry period KBDI could be in the 600+ range and large fuels have experienced deep drying. A single rain event could cause KBDI to drop into the 200 to 300 range. While the 1- and 10-hour fuels would be immediately impacted by the rain event the larger 100- and 1,000-hour fuels would still be extremely dry on the interior. Fire behavior could be much different than expected if the KBDI alone is used as a fire behavior predictor.

In Georgia, the number of fires and acres burned between 1957 and 2000 was highest in the months of February and March. This is when KBDI is typically lowest with August having the highest KBDI. Wildland fire incidents in Georgia corresponded especially to the spring fire season not the high KBDI months of summer (Chan and others 2004). The influence of fuel moisture on fire behavior is not well known for 100- and 1,000-hour fuels. This is particularly a problem in the Southeastern United States where there is extensive southern pine beetle damage. Many southern forests have heavy 100- and 1,000-hour fuel loading due to the southern pine beetle. This study applied six different rainfall events and monitored fuel moisture of 1,000-hour logs to see how moisture contents changed with different rainfall amounts and durations.

METHODS

This study was conducted on the Clemson Experimental Forest in Clemson, SC. We collected two types of logs, several species of the red oak group (Section Lobatae) and loblolly pine (*Pinus taeda* L.). The loblolly pine collection consisted of live and dead tree logs whereas the red oak logs were all collected from live trees. The three log size classes were: (1) 3 to 5 inches, (2) 5 to 7 inches, and (3) 7 to 9 inches in diameter. Each log was 3 feet in length with the cut ends untreated. Trees were cut down and then cut to meet the size classes required. The dead loblolly logs were collected from the forest floor and cut according to size class as well. The dead loblolly logs were left from a southern pine beetle cut and had been lying on the forest floor for approximately 1 year.

The cut logs were placed into a barn where they were allowed to dry well protected from rain. This barn was not temperature controlled. The logs stayed in the barn for a total of 2 years. In the second year fans were used to circulate air across the logs for 24 hours a day to aid in the drying process. Log moistures were regularly checked over 2 years to monitor the drying process. When the logs reached equilibrium they were removed from the barn to the treatment location as needed.

Rainfall treatment events began on April 7, 2008, and ran until complete on June 18, 2008 (table 1). Rainfall was applied

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Table 1—Rainfall treatments and treatment dates

Treatments	Treatment dates 2008
4 inches one time in 1 day	April 7
2 inches two times in 1 week	April 10, 15
1 inch four times in 1 week	April 15, 16, 17, 21
1 inch four times in 2 weeks	April 23, 25, 29
1 inch four times in 3 weeks	May 5, 11, 14, 21
1 inch four times in 4 weeks	May 29; June 3, 12, 18

with a Colorado State rainfall simulator which was placed on an open gravel lot in full sun (fig. 1). The gravel was covered with 3 inches of wood mulch to simulate the forest floor. Natural rainfall was not a factor as we did not have any during our experiment times. The rainfall simulator applied rain at a rate of about 1 inch per hour. Twenty-four logs from each log type (a total 72 logs) were placed on the mulch for each of the 6 rainfall events. The logs were placed on the mulch in a random order for each of the six events. We applied six rainfall events: (1) 4 inches in 1 day, (2) 2 inches two times in 1 week, (3) 1 inch four times in 1 week, (4) 1 inch four times in 2 weeks, (5) 1 inch four times in 3 weeks, and (6) 1 inch four times in 4 weeks.

Log moisture was sampled in two locations on each log prior to and after each rainfall event. The posttreatment log moistures were taken 24 hours following each rainfall event to allow time for the exterior of the logs to dry. We used a Delmhorst® J-Series compact wood moisture meter with a type 26-ES two-pin hammer probe electrode. Fuel moisture measurements were taken 1 foot in from each end of the log on top of the log through the bark at a depth of 1 1/8 inches.

Figure 1—Colorado State rainfall simulator with 72 logs underneath.

Equipment limitations made it impossible to replicate this study. We had only one rainfall simulator and limited logs for this study. This unreplicated case study simply shows mean moisture changes for each rainfall event in all three species and size classes of logs.

RESULTS

Pretreatment log moisture ranged from 11.2 to 23.2 percent with an average of 15.4 percent. Dead pines had the lowest pretreatment moisture contents with the live pines slightly higher. The dead pines had the highest posttreatment moisture contents for the 1 inch four times in 2 weeks and the 1 inch four times in 3 weeks. The oak and live pine log moisture contents stayed close after the first rainfall in all treatments. The dead pine had the highest increase in log moistures. The 4 inches in 1 day treatment showed the dead pines with higher moisture content than the live pines and oaks (fig. 2). The 1 inch four times in 1 week treatment rained on logs every other day for 1 week. For this treatment log moisture contents of all classes increased at a steady rate with the dead pines having the highest moisture contents around 32 percent (fig. 3). The 2 inches two times in 1 week treatment followed the same trend with increased log moistures after each rainfall event (fig. 4). The oaks once again show a slower increase in moisture content than the live and dead pine. One inch of rain four times in 2 weeks produced the wettest logs after the last treatment (fig. 5). The watering for this treatment had more time between rainfall events but not enough time to let the logs dry. All pine logs and the 3- to 5-inch oak logs all had moisture contents greater than 30 percent. Watering the logs 1 inch four times in 3 weeks showed the same steady increase with slightly lower moisture contents than the 1 inch four times in 2 weeks treatment (fig. 6). With all of the treatments there was a steady increase in fuel moisture over time except for the 1 inch four times in 4 weeks treatment (fig. 7). The amount of time between rainfalls may have been too great allowing the logs to dry before the next rainfall could be applied. Our treatments show that one rainfall event only impacts the log moisture content slightly except for the 4 inches one time in 1 day treatment. To reach log moistures in the high 20 to low 30 percent range we had to apply 1 to 2 inches of rain frequently over a 2- to 3-week period. We obtained the greatest moisture contents by applying 1 inch of rainfall four times over 2 weeks. The logs that received 2 inches of rain two times in 1 week also had a higher moisture content of 27.1 percent.

CONCLUSIONS

We know that KBDI alone is not a good indicator of fire behavior and intensity in the Southeast. After a single rainfall event KBDI can drop drastically but moisture contents of large woody fuels do not all increase appreciably. In this preliminary case study we were able to monitor log moisture content over time with different rainfall treatments. This study gives us a picture that one rainfall event will not greatly increase the moisture content of 100- and 1,000-hour fuels unless it is an event producing large amounts of rain. It takes several 1- to 2-inch rainfall events over time. The next step in this

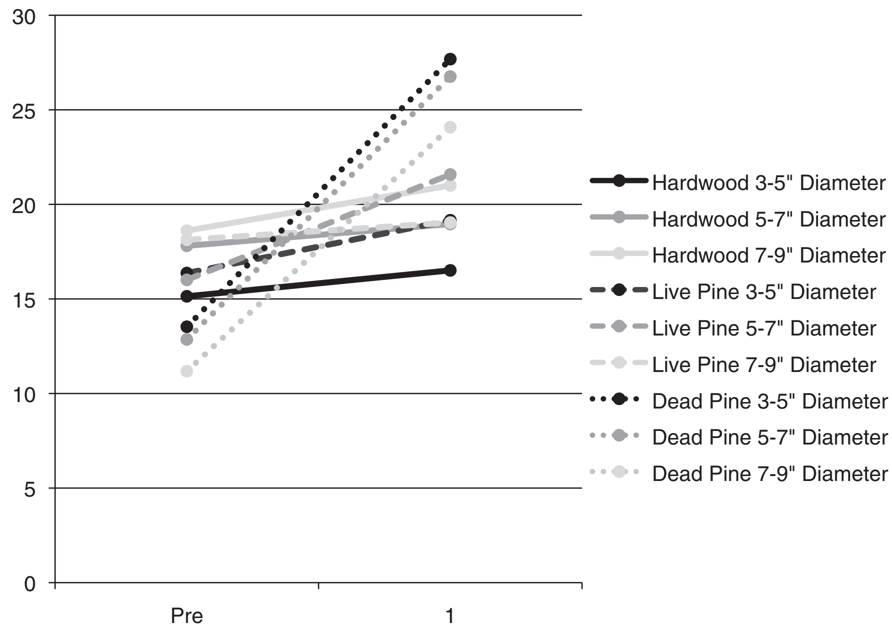

Figure 2—Average log moisture content (percent) prior to treatment (pre) and 24 hours after the rainfall event (1) for the treatment of 4 inches of rain applied one time in 1 day.

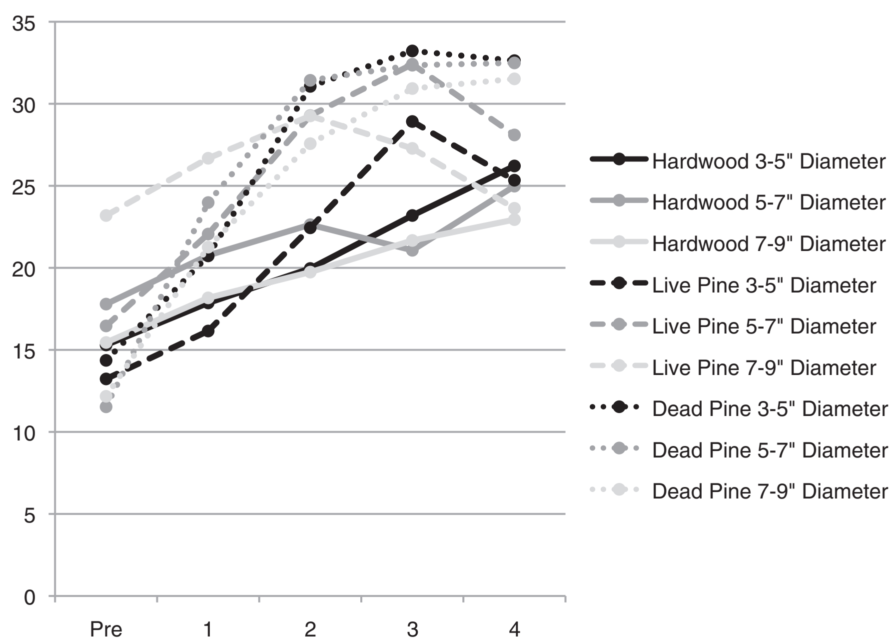

Figure 3—Average log moisture content (percent) prior to treatment (pre) and 24 hours after each rainfall event (1, 2, 3) for the treatment of 1 inch of rain applied four times over a 1-week period.

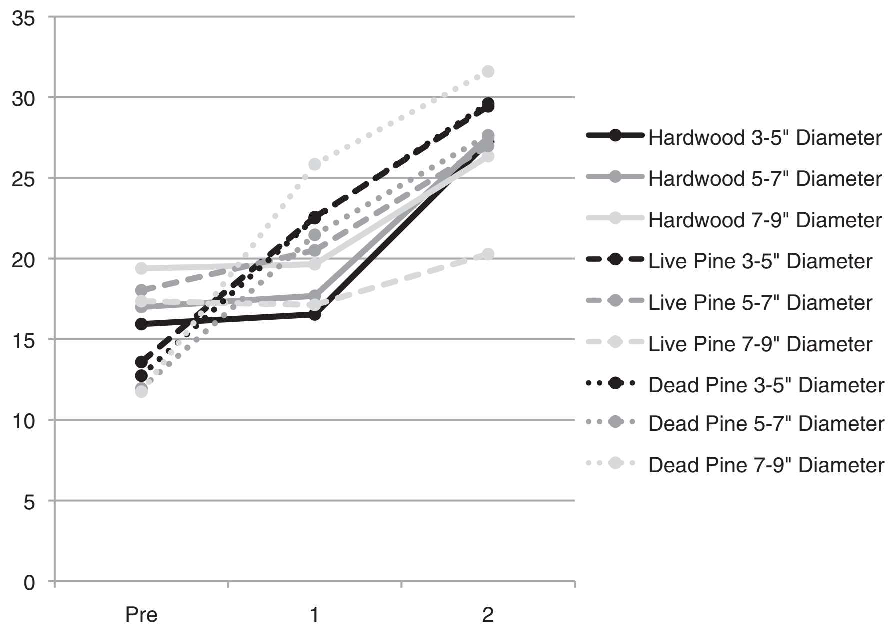

Figure 4—Average log moisture content (percent) prior to treatment (pre) and 24 hours after each rainfall event (1, 2) for the treatment of 2 inches of rain applied two times over 1 week.

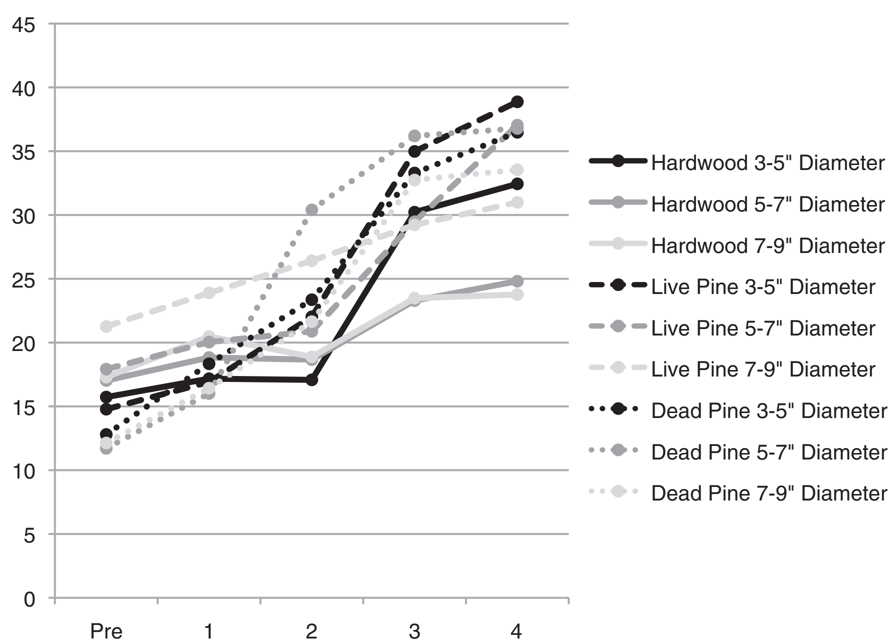

Figure 5—Average log moisture content (percent) prior to treatment (pre) and 24 hours after each rainfall event (1, 2, 3, 4) for the treatment of 1 inch of rain applied four times over 2 weeks.

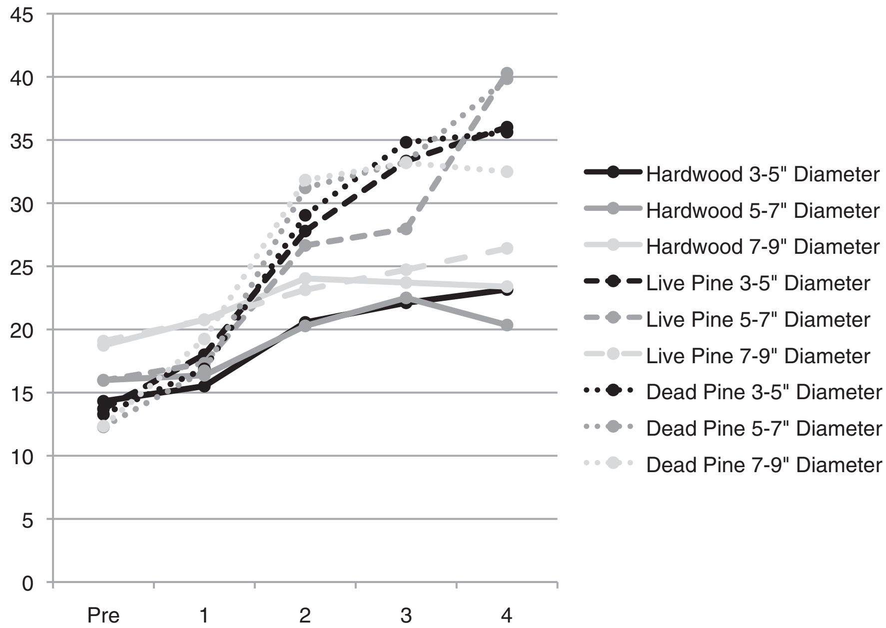

Figure 6—Average log moisture content (percent) prior to treatment (pre) and 24 hours after each rainfall event (1, 2, 3) for the treatment of 1 inch of rain applied four times over 3 weeks.

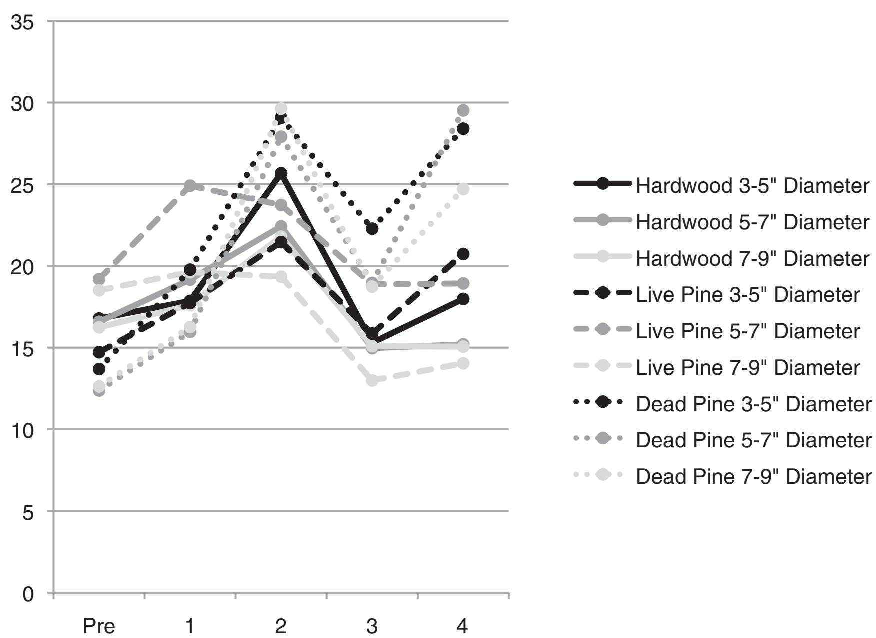

Figure 7—Average log moisture content (percent) prior to treatment (pre) and 24 hours after each rainfall event (1, 2, 3, 4) for the treatment of 1 inch of rain applied four times over 4 weeks.

study would be to replicate the treatments and add more rainfall events. Taking the wet logs to wooded areas that are scheduled for prescribed burns would then be the next step. Burning these logs in forested conditions would allow us to measure consumption due to the fire. The combination of log moisture data and log consumption may give us a clearer picture of fire behavior due to large woody fuels.

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LITERATURE CITED

Chan, David W.; Paul, James T.; Dozier, Alan. 2004. Keetch-Byram drought index: can it help predict wildland fires. Fire Management Notes. 64(2): 39–42.

Haywood, James D.; Stagg, Richard H.; Tiarks, Allen E. 2004. Relationship between Palmer's drought severity index and the moisture index of woody debris in the southern Coastal Plain. In Connor, Kristina F. ed. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-71. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 39–43.

Melton, Mike. 1990. Keetch-Byram drought index: a guide to fire conditions and suppression problems. Fire Management Notes. 50(4): 30–34.