Fire and Fuels Research at Fort Valley and Long Valley Experimental Forests

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Abstract—*Fire research began on the Fort Valley and Long Valley Experimental Forests in the mid 1970s. The U.S. Forest Service and other agencies in the Southwest (BIA and state) had been utilizing prescribed fire to reduce piled hazardous fuels from harvesting. Most managers had not viewed the use of prescribed fire to reduce natural fuels on a broad scale positively. The use of rotational prescribed burning has been investigated for over 30 years to determine the long-term effects of the reintroduction of this natural event. This paper summarizes the events that led up to the establishment of this long-term research project and general findings resulting from this work.*

Introduction

Since its inception in 1908, Fort Valley Experimental Forest has been the site of many research projects, mostly dealing with the ecology, silvics, and regeneration of ponderosa pine (*Pinus ponderosa*). Fire was viewed as a damaging agent, to be dealt with only after the fact, and guides were developed to salvage forests damaged by fire (Gaines and Shaw 1958).

It seems strange that early research never fully realized the critical role that fire played in many ecosystems, including long needled pines, notably ponderosa pine. Early researchers could hardly have missed the numerous fire scars on the old growth yellow pines. They may have been influenced by the prevailing view at the time—that trees were primarily for forest products and any injury reduced product value. In fact, the primary role of the forest manager was to perpetuate the species for the purpose of forest products by improving regeneration and growth rates, while utilizing overmature trees with low productivity. Thus, fire was considered a threat resulting in product damage or even mortality. They accomplished their goal of preventing fire from damaging valuable trees through pre-suppression measures including slash fuel reduction.

Even in the early 1970s forest managers did not discuss prescribed fire as an option largely due to the char produced on boles destined for pulp production. Fire was used only in the form of slash pile burning. This standard treatment of fuels was done in the winter months to further minimize the risk to trees, using the snow to keep fires from running beyond the piles through the woods willy-nilly.

In 1974, Jack Dieterich returned to the U.S. Forest Service Fire Research community from a tour in the Peace Corps. Upon his return, he was asked to head up a new fire research unit for the Rocky Mountain Forest and Range Experiment Station. I (Sackett) worked for Jack at the Southern Forest Fire Laboratory in Macon, Georgia, in the late 1960s, prior to Jack's service in the Peace Corps. For reasons of efficiency, the new fire research unit should have been located in Flagstaff, Arizona. However, the decision-makers at the time chose to establish the unit at the Forestry Sciences Laboratory on the campus of Arizona State University in Tempe, Arizona.

The first effort to explore potential fire conditions across the southwest region was to extensively survey the surface and ground fuel loadings in unharvested ponderosa pine/Arizona fescue ecosystem. Some mixed conifer stands were also included in this survey but the focus was on natural fuels of the southwestern ponderosa pine forest—the largest expanse of its kind in the world (Sackett 1979).

The results of that first fuel load survey were quite eye opening to many forest managers. Until then, when managers looked at fire hazard in the ponderosa forests, their focus was mainly the slash problem. The survey results revealed that, in fact, there was a serious natural fuel hazard even without the slash (Sackett 1979, Sackett and Haase 1996) with the potential for extreme wildfire behavior and high severity fire effects.

Four plots of the natural fuel survey were located on the Fort Valley Experimental Forest (FVEF) and Long Valley Experimental Forest (LVEF). The results of the survey showed total forest floor fuels less than 1-inch diameter ranged from 11.7-17.7 tons per acre. The mean of the 62 plots

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covering the southwestern range of ponderosa pine was approximately 12.5 tons per acre. The experimental forest plots averaged 2.2 tons per acre heavier.

After surveying the fuels over the entire range of southwest ponderosa pine, it became evident to us why current day wildfires in the region were stand-consuming in nature. Out of that evidence, questions arose. A key question was how these forests could have survived and actually thrived for so long historically if naturally ignited fires (lightning) destroyed entire sections of the landscape. We know that yellow pines alive today on FVEF plots were seedlings well before the discovery of America. Supporting this theory is the fact that the first fire scare recorded on one of the trees evaluated at FVEF occurred in 1540 A.D. (Dieterich 1980b). Subsequently, how could these forests survive with the removal of fire, if this extremely flammable ecosystem had received regular exposure to wildfire in the past?

Jack Dieterich set out to determine the actual historical occurrence of natural fire in ponderosa pine—a topic sorely overlooked by researchers investigating ponderosa pine, especially in the Southwest. He collected his initial samples along the eastern edge of the FVEF at an area we now know as Chimney Spring. His sample trees dated back to the 1500s and fire scars in the tree rings themselves were numerous. The natural fire-return interval was as short as 1.25 years. Over the entire span of time (1540-1876) the average interval between fires at Chimney Spring was 4.9 years. Jack's research clearly demonstrated that fire played a dominant role in the life of ponderosa pine prior to the Euro-American settlement of the Southwest.

Based on our survey, observations and experience in the southern species of yellow pine (loblolly and long leaf pines) where prescribed fire has been common practice for decades, Jack and I (Sackett) determined that natural fires were critical in maintaining the balance in ponderosa pine. With the combination of recent fire absence and high fuel hazard, the obvious management direction would be to replace the element (fire) that had been removed from the system as human settlement interrupted the natural process of the forest. It seemed clear that prescribed burning should be a primary option for protecting ponderosa pine forests from devastating wildfire. To test this, an ambitious prescribed fire research project was planned.

Before anything could be done to set up this prescribed fire study, we first had to decide where it could be established in a research context and how it would happen. Flagstaff was the obvious choice since there was an experimental forest there—Fort Valley. To begin exploring our options we first needed to talk with someone familiar with the area. That someone was Gil Schubert, "Mr. Ponderosa Pine." Gil was the leader of the Rocky Mountain Station at the Forestry Sciences Laboratory silvicultural research unit in Flagstaff. In addition, he was in charge of Fort Valley. Like many silviculturalists at the time, Gil was not too supportive of prescribed fire or fire research. Wildfire was to be fought and protected against. Prescribed fire was to be avoided. Jack's silver tongue finally persuaded Gil to let us look around for a site.

Our options for research plots were quite limited due to the number of historic studies and ones in process located throughout most of the experimental forest. We finally found a site adjacent to the Coconino National Forest on the eastern boundary of FVEF. According to Gil, nothing had happened to the site in the history of FVEF. Jack and I (Sackett) agreed to take it. Chimney Spring was the closest landmark, hence, we called our area Chimney Spring Prescribed Fire Research Area.

In 1976, Chimney Spring was divided into twenty-nine 2.5-acre (1 hectare) square plots. Twenty-one randomly selected plots had a 1-, 2-, 4-, 6-, 8-, or 10-year burning rotation or no burning (control) assigned three times (three replications per treatment). The remaining eight plots were set aside for future studies. The primary research goal was to determine how often it was appropriate to apply prescribed fire in order to keep the forest relatively safe from severe wildfire while assessing collateral fire impacts. From previous work, Jack and I knew that a single burn would not be adequate for continuous protection. In fact, a single burn can cause an increase in fuel for the period following the initial burn in the form of scorched crowns, increase of dead stems, and such.

Our research staff took many before-burn measurements in cooperation with folks at the Northern Arizona University School of Forestry. Vegetation transects were established by Dr. Lee Fitzhugh, wildlife professor, and runoff studies were conducted by Dr. Charles Avery. We contracted with NAU forestry students to survey overstory conditions while our technicians sampled fuel conditions. In hindsight, it may have been wise to wait another year to study and accumulate more and better pre-burn variables, but at the time, we chose to proceed with the data we had accumulated during that first summer.

The summer of 1976 was very dry. We postponed the initial burn a number of times. We consulted regularly with the Coconino National Forest staff to keep informed of conditions in order to select the appropriate and safe time to burn, avoiding burning under severe and potentially dangerous conditions. Our delays lasted into late fall and we realized that something had to be done. Bill Buck, Fire Staff Officer for the Coconino, suggested we might try to burn under cooler conditions at night and so we did. Using all the overhead of the Coconino National Forest and our technicians, we began ignition at Chimney Spring the evening of November 7, 1976.

The valley-slip air movement had already started moving down the San Francisco Peaks, so we carefully started applying fire at the bottom (south end) of the plots and worked our way toward the top. We all had plenty to do to get all of the burn plots completely ignited, keeping the fire moving without accidentally igniting the controls, and keeping the fire within the study boundaries. For these reasons, no one had much time to photograph the event. There was, however, a young professor at Northern Arizona University (NAU) who had an interest in what we were doing. Wally Covington was "savvy" enough to take some pictures of this historic and hectic event. Once the plots were ignited, they were left to burn all evening. In fact, they burned for the next two days.

Forest floor fuel loadings were heavy on these plots since no previous disturbance or fire had been noted since 1876—100 years previous (Dieterich 1980a). During our initial prescribed fire, 94% of the area consumed 64% of the weight of the fuel. Heavy scorching of "doghair" or sapling thickets took place as well as exposing of mineral soil in many places especially around large, mature yellow pines.

Chimney Spring is located just under the San Francisco Peaks making the soils basalt in nature. Since southwest ponderosa pine also grows on sedimentary soils, we thought it important, especially for fire effects research, to include a comparison study on sandy soils.

Fortunately for us, there was the Long Valley Experimental Forest (LVEF). After checking again with Gil Schubert, we duplicated the prescribed fire rotation study at LVEF, which is the Limestone Flats Prescribed Fire Research Area. We modified some of our sampling techniques based on what we learned from our experiences at Chimney Spring but the overall study design remained similar.

Long Valley was somewhat different from Fort Valley in ways other than soil type. Long Valley was not a "virgin" stand like Chimney Spring. The application of a sanitation cut over the area in the late 1960s during a wet March created some mechanical disturbances to the soil. In contrast to Chimney Spring, Limestone Flats, as we refer to it, was a more open stand, much like other parts of the vast ponderosa pine stands along the Mogollon Rim. The last recorded natural fire occurrence was in 1898, twenty-two years later than at the Chimney Spring site (Dieterich 1980b).

Unlike the summer of 1976, 1977 had an abundance of moisture during the monsoon season, so burning was not "all consuming" like the burning in the previous year. The ignition in 1977 occurred over a two-day period, October 26-27, which was almost as late as the original Chimney Spring burn.

Forest floor fuels, the heart of the energy system of wildland fire, are commonly defined as either fine, light fuels or heavier woody fuels. Fine fuels consist of needles and small twigs while heavier fuels are generally branch wood, tree boles, stumps, etc. The real heart of the fire lies in the consumption of the fine, new needles and small twigs that make up the vertical flames or fire intensity portion of the material. The older, decomposed needles, twigs, cones, etc. result in the fire severity and are associated with glowing combustion of the total wildfire phenomenon (Harrington and Sackett 1988, Sackett and Haase 1998). Total fuel loading at both sites was quite different at the start of the studies. Chimney Spring had almost 23 tons per acre where as Limestone Flats had about 32 tons per acre (Sackett 1980, Sackett and Haase 1996). Fine fuels, which most affect what happens to a site, were virtually identical—15+ tons per acre. The first Chimney Spring fire eliminated 65% of all fuels on the site whereas the wetter season fire at Limestone Flats eliminated only 43%.

In any case, the initial burns at both locations set in motion the return of fire to an environment that had been without the benefit of a valuable natural phenomenon for 70-100 years. The absence of fire, during the period when fire suppression was the rule, created problems in the ponderosa pine ecosystem that we are still trying to understand. Once seen as a grassland with scattered trees, the southwest ponderosa pine forest has turned into a system of very old trees and "never before seen" stands of millions upon millions of stagnated and unhealthy trees that were started in two good seed years in the early 1900s (Sackett and others 1994, 1996a,b).

Restoring fire and studying its effects has been and will continue to be the goal of fire research at the Fort Valley and Long Valley Experimental Forests. The initial burns of 1976 and 1977 began the research study that exists to this day. Knowing that a single burn was inadequate in having a "naturalizing effect" on any facet of the environment, our study sought to look at the effects of fire reintroduced on a recurring basis. Plots were assigned different burn intervals ranging from annual to 10-year rotations. To date, the annual plots have had fire applied 32 times, which is quite a feat. As previously stated, the original hypothesis was to determine the burn interval that would "protect" a ponderosa pine forest from severe wildfire damage. This is difficult to prove or even to test, but we can make inferences from the study data on fuels, crown height from ground, and other variables common to wildfire behavior. Figure 1 demonstrates before- and after-treatment stand changes over a 20-year period at the FVEF site. Figure 2 shows changes in stand structure after a 20-year period at the LVEF.

More importantly, these two study sites give us valuable information about the effects of fire associated with reinstalling the fire as a natural phenomenon in the ponderosa pine forests. What does burning do to the soil? What are the effects on vegetation composition and growth? What does fire do to soil moisture? We and other cooperators have been studying these and other questions during the years of this ongoing research.

Bringing fire back into a heavily fire dominated ecosystem after so many years of exclusion creates situations that are completely unpredictable. Some responses make perfect sense after a little thought. One such example was our attempt to understand an unexpected, yet significant negative impact of the prescribed burns: the mortality of large numbers of the yellow pine following the first entry burns. When some managers in non-fire disciplines view this result, any further discussion of using prescribed burning is almost shutdown.

As previously mentioned, there are two types of forest floor fuels associated with how fire behaves. First is the fine, light, relatively new needle fuels that affect fire intensity. The second, fire severity fuels, consist of decomposed dense fuels below the top layers that burn more with glowing combustion than with flaming combustion. Southwest ponderosa pine forests are very dry systems. Desert or dry pinon/juniper ecosystems surround our vast stands of ponderosa pine. Due to the dryness of our forests, decomposition manifests itself extremely slowly, resulting in heavy forest floor accumulations. These factors cause us to focus on the flaming front of a fire and to ignore the glowing combustion that takes over after the frontal passage of a fire.

Figure 1. Stand changes on a 4-year burn rotation treatment plot at Chimney Spring research area are shown by comparing photo (a) that was taken prior to the burn treatment in 1976 and photo (b) that was taken in 2002.

Figure 2. Example of stand changes on a 4-year burn rotation treatment plot at Limestone Flats research area. Compare photo (a) taken prior to the burn treatment in 1977 to photo (b) that was taken in 2002.

Old yellow pines tend to accumulate large amounts of fuel around their bases resulting in tremendous amounts of potential energy that lies dormant until glowing combustion ignites it. During one of our burns, we began digging around the base of an old yellow pine. Inadvertently, we struck a root while using a tool. As the root split open, exposing the suberized layer, steam escaped. We exclaimed, "Oh yes, it is hot down there!" This experience led us to conclude that real, yet not obvious damage can occur in the soil when there is no apparent damage in the crown or on the bole of the tree.

The greatest unnatural and problematic portion of these untreated ecosystems is the extremely heavy fuel loads around the bases of mature yellow pines. After-the-fact measurements indicate unusually high fuel loadings, ranging from 38 to 121 tons per acre equivalent right at the base of individual trees. The range of fuel loads under the tree canopy range from 19 to 116 tons per acre equivalent. These fuel load conditions demonstrate the need for mitigating measures if large, old trees are to remain a part of the system.

Our original premise with regard to mortality of these veteran trees was that the root systems were affected by soil heating (fire severity) while the heating at the bole of the tree was conducted through the bark into the cambium, the living cells of the tree. Loss of roots and girdling of the bole are "sure fire" ways to increase tree mortality. If, as we surmised, one could eliminate one of the two problems, the tree might survive the unnaturally extreme heat flux of a first entry burn. We felt that the easiest solution would be to eliminate the fuel from around the base of these prized mature trees. In fact, our studies at FVEF and LVEF showed us that taking away the forest floor fuels around the base of "saver" trees could eliminate the heat flux on the boles. This process, although quite labor intensive, is greatly enhanced with the use of a backpack leaf blower. Not only does the blower eliminate the forest floor, it scatters it out away from the heaviest fuel accumulations close to the boles.

The research on old-growth tree mortality started at that moment (Sackett and Haase 1991, 1998). Since then, soil and cambium temperatures have been measured on more than 100 individual trees in Regions 3 and 5. Soil temperatures are measured at six depths down to at least 10 inches at 3 to 4 locations beneath the individual tree's canopy while six cambium temperature points are measured on each tree under "normal" prescribed fire conditions (Figure 3). The obvious conclusion shows excessive heating both of root systems and at the growing cells of tree boles (cambium).

Decades without fire in a fire-adapted forest has created the current artificial and unnatural ecosystem. Modified means are necessary to reintroduce fire back into the system. Much of the work at Fort Valley and Long Valley gave us valuable insights into reestablishing fire into an old over-protected system. Forest managers are realizing the need to restore fire to ecosystems that have historically incorporated fire as a natural part of the system and see the benefits that go beyond just fuel reduction.

Figure 3. Soil and cambium temperatures being measured during a prescribed fire at Limestone Flats research area where the forest floor material has been removed around the base of the tree.

Conclusion

As we answer questions regarding the use of prescribed fire in the southwestern United States, scientists and managers raise additional questions. Examination of the fire seasons in the most recent past demonstrates the successes of using prescribed fire in wildland/urban use areas. The increased number of acres treated with prescribed fire allows fire managers to successfully function under the current directive of Appropriate Management Response (AMR), allowing wildfire or wildfire use to do what occurs naturally in areas. Reduction of this natural fuel buildup by prescribed burning expands allowable burning conditions. There is no guarantee that a management tool such as prescribed burning is perfect, but with additional use and experience, the success of fire as a tool is improved. Forest Service research as well as university cooperative research has been responsible for looking at many of these fire effects (see Appendix A). We are proud of the successes of these students, many of whom are productive Forest Service or university researchers in their own right in other geographic areas of the United States. We take great pride in knowing that we have had a small role in their career. We are also grateful to the grant process of the Joint Fire Science Program for funding to remeasure critical variables (ground and canopy fuels, stand overstory conditions, soil ammonium and nitrate, vegetation density and diversity) after 30 years of research. The goal is to evaluate more than thirty years of repeated rotational prescribed burning treatments in southwestern ponderosa pine, a truly rare opportunity.

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Appendix A

This appendix contains graduate student research theses pertinent to Chimney Spring and Limestone Flats that have been produced from 1978 through 2008 in cooperation with the School of Forestry at Northern Arizona University, University of Arizona, and Arizona State University. Also included are journal articles, proceedings, research notes, and other publications resulting from the graduate work and additional publications not included in the citation section.

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