Effects of Prescribed Fire and a Wildfire on Oak Savannas in the Peloncillo Mountains of the Southwestern Borderlands Region

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The Southwestern Borderlands Region of Arizona, New Mexico, and northern Mexico are known for its biological diversity and beauty. The area is characterized by its mountains surrounded by deserts and grasslands. The region contains representative animals and plants from the Rocky Mountains in the north to the Sierra Madre Mountains to the south. Madrean oak woodlands and savannas are common within the area covering millions of acres. Periodic fires caused by lightning or Native American people maintained the grasslands and reduced the encroachment of woody vegetation and the accumulations of woody fuels. However, the role of fire declined after the transcontinental railroad was completed and large herds of cattle were introduced into the area. Fires are still ignited but do not spread throughout the landscape largely because overgrazing caused a decline in herbaceous vegetation which carried fires. Aggressive fire suppression by land managers also contributed to the reduced influence of fire.

Public and private land managers are concerned that the lack of fires in the Borderlands Region is to blame for the increase in woody species and the decline in biological diversity and productivity of the grasslands and savannas. The Peloncillo Programmatic Fire Plan was developed by the Coronado National Forest to re-introduce landscape level prescribed and managed fires into Forest Service and Bureau of Land Management lands within the Peloncillo Mountains (Gottfried et al. 2009). One of the issues was whether it was best to burn in the cool-season (November-April) or the warm-season (May-October) because of concerns about potential harm to the threatened New Mexican ridge-nosed rattlesnake (*Crotalus willardi obscurus*) and the endangered Palmer agave (*Agave palmeri*). The agave is important because it provides food for the endangered lesser long-nosed bat (*Leptonyceris curasoae*). The area usually burns during the warm period prior to the monsoon season.

The Cascabel Watershed Study

There was a lack of information about the overall effects of fire in the savanna ecosystem. The Forest Service's Rocky Mountain Research Station through its Southwestern Borderlands Ecosystem Management Unit initiated the Cascabel Watershed Study. The objective was to evaluate the effects of fire on as many savanna ecosystem components as feasible. The study was initiated in 2000 in a Madrean oak savanna on the southeastern flank of the Peloncillo Mountains in Hidalgo County, New Mexico. Emory oak (*Quercus emoryi*) and alligator juniper (*Juniperus deppeana*) are the dominant tree species but are associated with Arizona white oak (*Q. arizonica*), Toumey oak (*Q. toumeyi*), redberry juniper (*J. coahuilensis*), border pinyon (*Pinus discolor*) and the tree form of mesquite (*Prosopis glandulosa* var. *torreyana*). Perennial grasses include several species of grama (*Bouteloua* spp.), Texas bluestem (*Schizachyrium cirratum*), and other species. Elevations range from 5,400 to 5,600 ft. The bedrock is Tertiary rhyolite overlain by Oligocene-Miocene conglomerates and sandstone (Youberg and Ferguson 2001). Soils have been classified as Lithic Argustolls, Lithic Haplustolls, or Lithic Ustorthents (Robertson et al. 2002). Streamflow is intermittent although large flows occur following high intensity rain storms (Gottfried et al. 2006). Annual precipitation has only been about 15 inches during the current drought. More than 60% of the annual precipitation occurs during the summer monsoon period. Recent livestock use has been light because herds were reduced due to the drought. The Cascabel Watersheds are located in the ecotone between the grasslands of the Animas Valley and the woodlands of the Peloncillo Mountains. Additional information about the Cascabel Study can be found in Gottfried et al. (2012).

Instrumentation and Measurements

Twelve small watersheds ranging in size from 20 to 60 acres were instrumented for the study. Each watershed contains two Parshall flumes; one flume has the capacity of 4.0 cfs to measure the common low flows and the other has a capacity of either 42.7 or 57.5 cfs to measure larger flows. Hydrologic stage is measured by electronic pressure sensors that are downloaded in the field to laptop computers and

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the data are transferred to computers at the Southwest Forest Science Complex in Flagstaff for analyses. Weather information is collected at two full weather stations, one on the eastern side of the area and one in the middle of the area. These stations collection information on precipitation, temperature, humidity, and on wind speed and direction. Precipitation data is supplemented by seven recording tipping bucket gauges. Each watershed has a sediment dam and basin and several permanent points upstream for measuring changes in channel morphology.

Measurements of vegetation, fire effects, fuel conditions, soil erosion and deposition, and wildlife are collected at permanent sample points that are established on transects that cross the watersheds perpendicular to the channel and run from ridge to ridge. The number of points varies from 35 to 45 depending on watershed size and shape. There are 421 points at Cascabel. Points or a subset of points, depending on the resource, are sampled in the spring and in the autumn following the winter or summer precipitation periods.

Treatments

The pre-treatment period at Cascabel ran longer than anticipated because of the regional drought and the small number of measurable flow events. Sufficient streamflow data were collected by 2007 but the prescribed burning was delayed until 2008 because of dangerous fire conditions. The 12 watersheds were divided into four groups of three treatments-cool-season prescribed burn, warm-season prescribed burn, and control based on the hydrologic record (Fig. 1). On March 4 and 11, 2008, the four watersheds designated for the cool-season burn (Watersheds C, H, K, and N) were treated by the Douglas Ranger District fire crew. Three of the warm-season watersheds (Watersheds A, E, and F) were treated on May 20. It was getting dark and weather conditions were in flux, so ignitions were suspended. The next morning, on May 21, some of the engines and crews were diverted to another fire. Later that morning, winds picked up and blew burning material across the fire lines and ignited the vegetation in the remaining warm-season watershed and the four control watersheds. Wind speeds were measured at 42 mph at the weather station and at 60 mph on the fire line. The resulting fire, called the

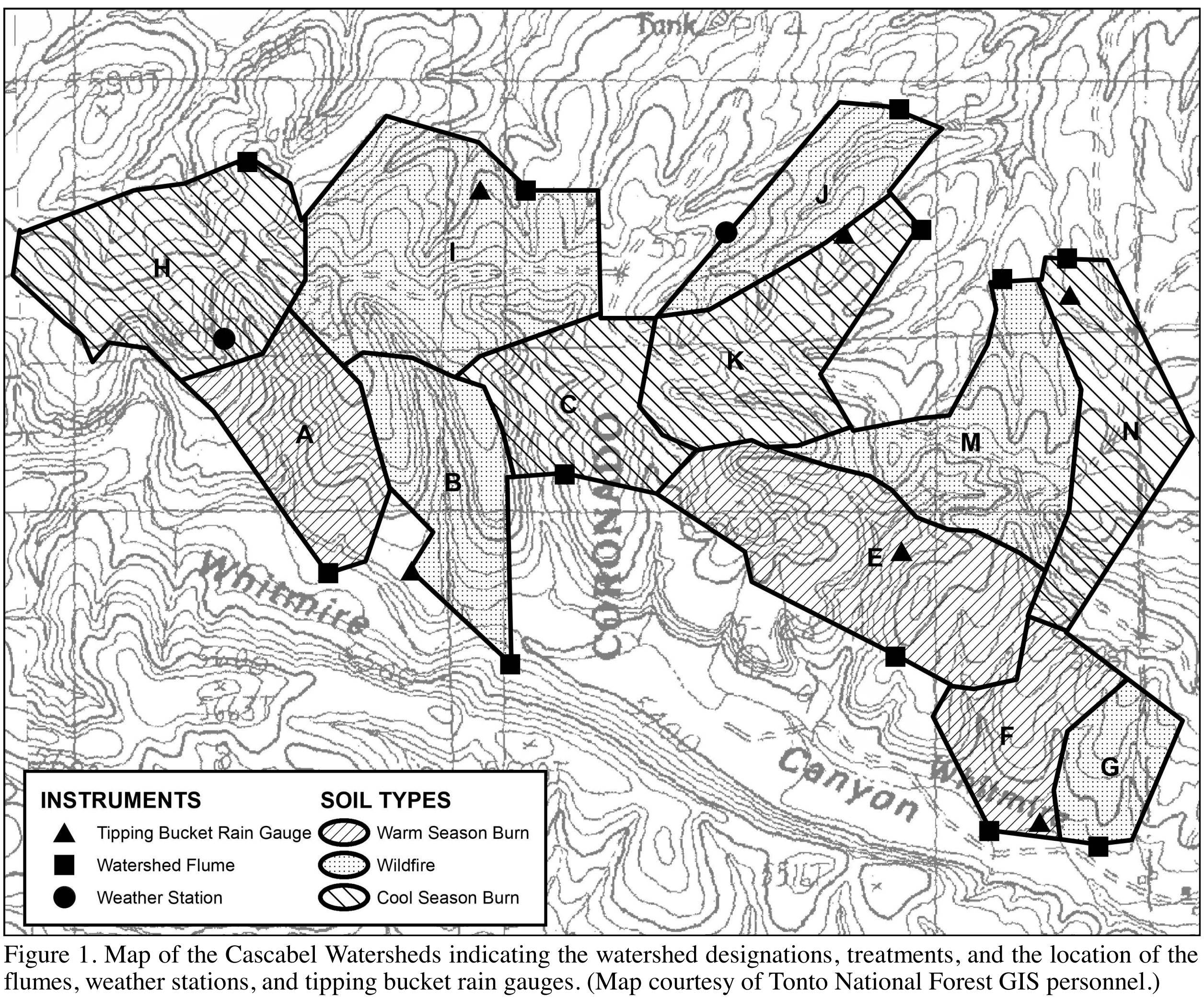

Figure 1. Map of the Cascabel Watersheds indicating the watershed designations, treatments, and the location of the flumes, weather stations, and tipping bucket rain gauges. (Map courtesy of Tonto National Forest GIS personnel.)

Whitmire Wildfire, burned approximately 4,000 acres. The experiment was redesigned to evaluate the effects of a cool-season burn (4 watersheds), a warm-season burn (three watersheds) and a wildfire (five watersheds) on the resources of the oak savanna.

Fire Severity

Fire severities were determined at the 421 sampling points using the system developed by Hungerford (1996) that relates fire severity to the appearance of litter, duff, woody material, and soil conditions with a range from low to high (Stropki et al. 2009). Severity ratings at the points on each watershed were extrapolated to a watershed basis to determine the percentage of the watershed that was unburned or burned at different severities. All watersheds were burned at low severity and there were no differences among burn treatments; therefore, data were combined to compare pre-treatment and post-treatment conditions for several treatment parameters.

Results

A number of articles that describe pre-treatment conditions on the watersheds have been published (Gottfried et al. 2012). While some post-treatment articles have been published, a comprehensive evaluation of the fire effects remains in the future.

Physical Attributes

Hydrology

A limited number of streamflow events have occurred since the fire treatments because of the regional drought, and therefore, comparisons between pre-treatment and post-treatment peak streamflow and volumes, and differences among treatments have not been fully calculated at this time. At least 30 events are needed for satisfactory analyses. However, hydrologic records from the seven years before the treatments and meteorological records since 2002 indicate high variability among the 12 watersheds. A storm in August 2005, which produced as much as 2.99 inches at one of the precipitation gauges, resulted in flows that overtopped four of the large flumes (Gottfried et al. 2006). The highest calculated flow for that storm was 76.8 cfs on Watershed H, at the northwestern part of the research area.

Soil Water Repellency

Water repellency, which impacts infiltration of water into and through the soil, was evaluated at the 421 sampling points using the Letey et al. (2000) drop test. The occurrence and levels of soil water repellency were limited in extent or magnitude regardless of fire treatment. No water repellency was found on 90% of the points. The other points had slight water repellency or moderate or strong repellency (Stropki et al. 2009). Burned and unburned points were grouped together. There were no statistically significant differences among watersheds with different fire treatments. Neary et al. (2010) found that most fuel types showed slight repellency, however, extreme repellency was mainly measured under woody debris and beargrass (*Nolina microcarpa*) clumps.

Ground Cover

The percentage of ground cover of plant material, litter, slightly decomposed organic debris on the soil surface, bare soil, and bedrock were determined around the sampling points (Ffolliott et al. 2011b). There were no statistical differences among watersheds and burning treatments. Bedrock, litter, and plant material were the largest component of the ground cover prior to treatment. There were significant increases in the percentage of plant material and bedrock after the fires while the relative amounts of litter and bare soil declined.

Hillslope Erosion

The erosion of hillslopes and deposition were measured at every third sample point within each watershed. The largest erosion occurred after the August 2005 storm when 27.56 tons/acre of soil was eroded (Kauffman 2009). The August measurements exceeded erosion in the subsequent two years. Upper hillslope positions lost less soil than middle and lower slope positions while deposition was greater on the lower hillslope positions than on the middle and upper positions. Deposition did not vary by year but was statistically different between fall and spring. There were some differences within watersheds receiving the same treatment. There was more erosion after the cool-season burn than before and there was more deposition after the wildfire than before. Initial measurements of erosion and deposition rates before and after the fires for all treatments were compared and no statistical differences were determined. The low amount of statistical differences can be related to the fact that all watersheds experienced low severity burns and had little or no soil water repellency (Stropki et al. 2009).

Channel Dynamics

Koestner (2012) examined channel changes on the 12 watersheds based on measurements in 2003, 2006, and 2009. They measured 142 channel cross-sections. None of the burn treatments had a significant effect on changes in channel cross-section area or cross-section shape. They concluded that small bedrock lined watersheds burned at low to moderate severity are not at risk for increased sedimentation due to fire. However, the regional drought and the lack of high intensity storms may have contributed to the relative stability of the Cascabel channels. Koestner (2012) postulated that low-severity burns and drought may have a similar impact on erosion because of reductions in herbaceous cover and increased exposure of bare grounds without impacting soil texture and sensitivity to erosion.

Biological Resources

Overstory Tree Cover

The overstory tree density was measured before and after the three fire treatments (Ffolliott et al. 2011c). Results were pooled together because all 12 watersheds received low severity burns and differences among treatments were not observed. Approximately 78% of the trees that were present before treatment survived initially. Eighty percent of the oak trees of all species and 75% of the juniper trees of all species survived. It is assumed that most damage was caused by convection heating from the surface fires. The crowns of 80% of the surviving oak and juniper trees, regardless of species, were scorched or top killed. Basal sprouting was observed on 37% of the surviving oak and 11% of the surviving juniper trees. A greater number of the large trees (≥9 inches diameter at root collar) survived than small or medium trees but crown damage was more severe on the larger trees possibly because of greater fuel accumulations adjacent to the trees. Species richness and spatial distribution were not impacted by treatment. In recent years, increased overstory tree mortality has been observed throughout Cascabel and could be the influence of the extended drought on the injured trees. A subsequent tree inventory would be beneficial to evaluate this situation.

Herbage Production

Estimates of the production of early- and late-growing grasses, forbs, and total herbage were obtained before and after the burning treatments using the weight-estimate procedure outlined by Pechanec and Pickford 1937). The species composition of herbaceous plants and shrubs were similar before and after the prescribed burns and wildfire (Ffolliott et al. 2012b). However, there were some differences related to treatments afterwards. The production of perennial grasses in both the spring and fall was significantly greater following the burning events relative to pre-treatment conditions. Depending on the event, there was a five- to seven-fold increase in the production of early-growing grass species. Increases in the production of late growing grasses following the burns was significant but of a smaller magnitude. The greater production could be related to reduced interception and water consumption by the remaining open tree canopy, reduced interception by the forest floor, and to increased nutrients left after the vegetation, litter, and duff consumed by the fires.

The production of forbs was significantly less than the production of grasses. Results were inconsistent. Neither the production of early-growing nor late-growing forbs was altered by the cool-season burn. Forb production of early-season forbs increased after the warm-season burn and the wildfire but production did not increase for late-growing species after these treatments. The growth of shrubs was not affected by the fire treatments. However, the growth of tree basal sprouts reported earlier was greater before treatment than after the fires.

Agave

Agave plants were not tallied on the sampling plots before the fire treatments. However, the post-treatment survey found agave on about 13% of the plots. None of the sampled plants had been damaged by the treatments although dead and damaged agave plants were noted by Ffolliott et al. (2010) in adjacent areas. It should be noted that some of the observed mortality may be related to the fact that these agave normally will die shortly after they produce their seed stalks. There was no pattern in the location of dead or damaged agave.

Wildlife

The prescribed burning season and the wildfire did not affect the use of the watersheds by two keystone species – Coues white-tailed deer (*Odocoileus virginianus couesi*) and the desert cottontail (*Sylvilagus auduboni*) (Ffolliott et al. 2012a). Fecal pellet-groups were counted at the permanent sampling points in the spring, after the winter rains, and in the autumn, after the summer monsoon. Counts were higher in the spring than in the autumn for both species. The deer appear to stay in the lower elevation savannas during the winter and spring and move to the higher elevation woodlands in the summer. Higher spring counts for the cottontail could be related to reproduction during the winter and lower autumn counts could be related to predation during the summer.

Surveys of bird species and numbers were conducted around a sub-set of sampling points during the spring and autumn before and after the fire treatments (Ffolliott et al. 2011a). Some species were tallied occasionally, while other species were observed more frequently. More bird numbers and species were tallied in the autumn. Some common sightings included the Ash-throated Flycatcher (*Mylarchus cinerascens*), Bushtit (*Psaltriparus minimus*), and the Mexican Jay (*Aphelocoma ultarmarina*). A more complete list of species can be found in Ffolliott et al. (2011a). However, it was difficult to isolate the effects of fire because of the large variability in tallies throughout the study.

Herpetological studies were conducted, primarily because of the concern about the effects of fire on the New Mexico ridge-nosed rattlesnake. None of these snakes were found at Cascabel in either the pre-treatment of post-treatment periods (Goode and Parker 2013). However, 8,951 lizards belonging to

10 species were identified on the watersheds. It is difficult to draw any conclusions about the effects of fire on the lizard population because of the variability of rainfall, vegetation cover and lizard numbers on the individual plots. A preliminary conclusion was that the fires did not affect the lizard populations.

Data Management

A geographically-referenced multiple-resource data management system has been developed for the Cascabel Study (Chen et al. 2009). The system is designed to enable researchers and land managers to store, interpret, and analyze data collected at Cascabel using a readily available computer program. The system should be applicable to other oak savanna within the Southwestern Borderlands Region.

Climate Change in the Borderlands

Climate models predict that the arid Southwest will become drier during this century and that this transition is already occurring (Archer and Predick 2008, Seager et al. 2007). These models predict that temperatures will increase, precipitation will fluctuate, and there will be an increase in extreme weather. These changes could affect the density and viability of less drought-tolerant species of plants and animals causing some of them to disappear. More drought tolerant invasive species may replace the native plants. A warmer and drier climate would affect water supplies for ranchers and wildlife and increase the potential for more frequent and larger wildfires. Cascabel with more than 10 years of meteorological, hydrologic, and ecological information would be ideal for monitoring climate change within the Borderlands. Cascabel data could be combined with information from other sites within the Borderlands of the United States and Mexico to provide a bi-national view of climatic dynamics in the greater Southwestern Borderlands Region.

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