WATER REPELLENT SOILS FOLLOWING PRESCRIBED BURNING TREATMENTS AND A WILDFIRE IN THE OAK SAVANNAS OF THE MALPAI BORDERLANDS REGION

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Water repellent (hydrophobic) soils impact the infiltration process of a water budget by restricting the movement of water into and through a soil body. The infiltration of water into a water repellent soil can be inhibited or completely impeded in which case much of the incoming precipitation reaching the soil surface becomes overland flow. One mechanism causing the formation of water repellent soils is the distillation of organic compounds in the litter and duff layers during combustion in a fire (DeBano 1981, 1999, 2003, Doerr et al. 2000). This mechanism resulted in the formation of water repellant soils following prescribed cool and warm season burning treatments and a wildfire on the Cascabel Watersheds in the oak savannas of the Malpai Borderlands Region in the eastern part of the Coronado National Forest. This paper complements the findings of an earlier study on the formation of water repellency on selected sites locations classified by accumulations of litter and other organic debris or dominant tree species on the watersheds before the fires (Neary et al. 2008) by reporting on the occurrences and levels of water repellency on a watershed-basis. An attempt to correlate the occurrences and levels of water repellency to the severity of the prescribed burning treatments and the wildfire is also presented.

PRESCRIBED BURNING TREATMENTS AND THE WILDFIRE

The original objective of the multi-purpose research program on the Cascabel Watersheds (Gottfried et al. 2000, 2007, Gottfried and Edminster 2005, and others) was to evaluate prescribed warm season (May through October) and cool season (November through April) burning treatments in relation to unburned control watersheds on selected ecosystem resources and hydrologic-functioning relationships in the oak savannas ecosystem. Following their calibration, four of the watersheds were burned in the cool season of early March 2008. Three of the four watersheds to be burned in the warm season were (in facto) burned on May 20, 2008, with ignition of the remaining watershed scheduled for a later date. However, wind gusts up to 60 mph the following morning blew fire brands from the previous day onto the remaining unburned warm season watershed and the four control watersheds. The resulting wildfire crossed the control lines between the Cascabel Watersheds in three places to burn nearly 4,000 acres on and adjacent to the watersheds. As a consequence of the wildfire, the original objective of the research program was modified to accomplish the goals of the research program by evaluating the impacts of the cool and warm season burning treatments and the wildfire on ecosystem resources and hydrologic-functioning.

STUDY AREA

Twelve small watersheds on the eastern side of the Peloncillo Mountains in southwestern New Mexico, the Cascabel Watersheds, were the study area. The areal aggregation of these watersheds is 451.3 acres. They are situated between 5,380 and 5,590 feet in elevation. The nearest long-term precipitation station indicates that the annual precipitation in the vicinity of the watershed averages 23.5 inches, with about one-half of the precipitation occurring in the monsoonal summer. Geological, physiological, and vegetative characteristics of the watersheds are described elsewhere (Osterkamp 1999, Gottfried et al. 2000, 2007, Youberg and Ferguson 2001, Neary and Gottfried 2004, Gottfried and Edminster 2005, Ffolliott et al. 2008, and others) and, therefore, are not presented in this paper.

STUDY PROTOCOL

On each of the watersheds, between 35 and 45 plots have been placed on randomly established transects perpendicular to the main stream channels and situated from ridge to ridge to provide the sampling basis for measuring ecosystem resources and evaluating the hydrologic functioning on the watersheds. Intervals between the plots vary depending on the size and configuration (shape) of the watershed sampled. A total of 421 plots were located on the watersheds. Occurrences and levels of water repellent soils were determined on these plots in the fall of 2008, approximately four months after the warm season burning treatment and the (nearly) simultaneous wildfire.

Litter, duff, and other organic debris were removed from each plot at this time, a drop of water was placed on the soil surface with an eye dropper, and the time it took for the drop of water to penetrate the soil surface was recorded (Letey et al. 2000). This procedure was then repeated at the plot because the location of a water repellent layer (if a hydrophobic layer existed) was unknown. The longest of the two times recorded for the drop of water to penetrate the soil surface was related to

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the following criteria of the National Wildfire Coordinating Group (Clark 2001) to determine the levels of water repellency:

- No repellency
- Slight repellency - less than 10 seconds for a drop of water to penetrate the soil surface
- Moderate repellency - 10 to 40 seconds for a drop of water to penetrate the soil surface
- Strong repellency - more than 40 seconds for a drop of water to penetrate the soil surface

A classification system relating fire severity to the soil-resource response to burning (Hungerford 1996) was the basis for assessing the severities of the prescribed cool and warm season burning treatments and the wildfire at the plots. Hungerford's system of classifying fire severity (DeBano et al. 1998, Neary et al. 2005, and other references on fire effects) is:

- No fire.
- Low fire severity – low soil heating or light ground char occuring where litter is scorched, charred, or consumed, while duff is left largely intact although it can be charred on the surface. Woody debris accumulations are charred or partially consumed. Mineral soil is not changed. Soil temperatures at 0.5 inch are less than 125°F. Lethal (fatal) temperatures for soil organisms occur to depths of 0.5 inch. The lethal temperatures for most soil organisms range upward to 212°F (BeBano and others 1998).
- Moderate fire severity – moderate soil heating or moderate ground char occurring where the litter and the duff is deeply charred or consumed. Woddy debris is mostly consumed except for logs that are deeply charred. Underlying mineral soil is not visually altered. Soil temperatures at 0.5 inch can reach 212 to 392°F. Lethal temperatures for soil organisms occur down to depths of 1.2 to 2.0 inchs.
- High fire severity – high soil heating or deep ground char occurring where the duff is completely consumed and the top of the mineral soil is visibly reddish or orange. Color of the soil below 0.5 inch is darker or charred organic material. The char layer can extend to a depth of 4 inches or more. Logs can be deeply charred or consumed and deep ground char can occur under slash concentrations or burned-out logs. Soil texture in the surface layers changed and fusion evidence by clinkers can be observed. All shrub stems, if present, are consumed and only the charred remains of larger shrubs are visible. Soil temperatures at 0.5 inch are greater than 485oF. Lethal temperatures for soil organisms occur to depths of 3.5 to 6.4 inches.

RESULTS AND DISCUSSION

The occurrences and levels of water repellent soils on the Cascabel Watersheds following the prescribed cool and warm season burning treatments and the wildfire were limited in both extent and magnitude. No water repellency was found on about 90 percent of the plots on the watersheds, slight water repellency was measured on 5 percent of the plots, and a level of either moderate or strong levels of water repellency was measured on the remaining plots (Figure 1). This general pattern prevailed regardless of the prescribed burning treatment or the wildfire. The limited occurrences and levels of water repellent soils found on the watersheds were not necessarily surprising, however, because the severities of the burning treatments and the wildfire were all comparatively low according to Hungerford's classification system.

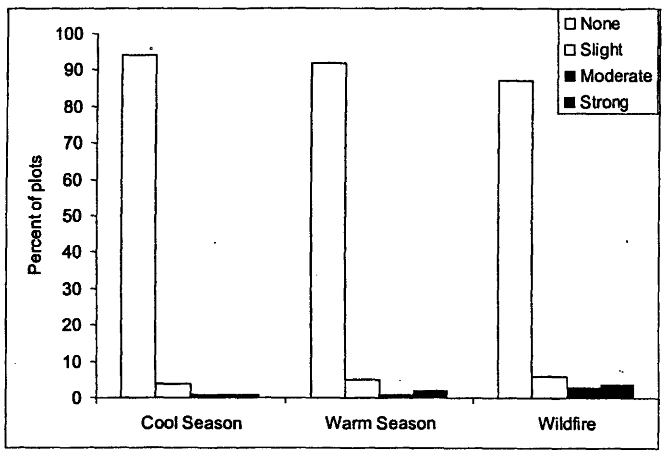

Figure 1. Occurrences and levels of water repellent soils on the Cascabel Watersheds following the prescribed cool and warm season burning treatments and the wildfire. The levels of water repellency are based on the criteria of the National Wildfire Coordinating Group (Clark 2001).

It was initially "hypothesized" by the authors that the occurrences and levels of water repellent soils might be related to the severities of the two prescribed burning treatments and the wildfire. However, the fire severities of the prescribed cool and the warm season burning treatments were not detected or classified as low on nearly 95 percent of the plots on the watersheds experiencing the two burning treatments, while moderate fire severity was observed on the remaining 5 plots (Figure 2). On the watersheds burned by the wildfire, no effects of the fire on the soil resource were observed on 5 percent of the plots, nearly 75 percent of the plots were burned by a low severity fire, and about 20 percent of the plots had experienced a moderate fire severity. None of the plots on the Cascabel Watersheds were exposed to a high severity fire by the prescribed burning treatments or the wildfire. However, there were pockets of high severity fire reported on burned sites where litter, duff, and other organic debris had accumulated before the fires (Neary et al. 2008).

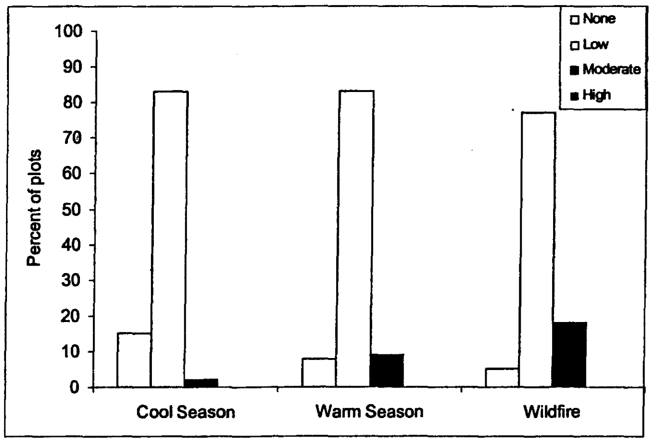

Figure 2. Fire severities of prescribed cool and warm season burning treatments and the wildfire on the Cascabel Watersheds. The fire severities are based on a classification system relating fire severity to the soil-resource response to burning (Hungerford 1996).

Little or no correlations were found between the occurrences and levels of water repellent soils and fire severities of the prescribed burning treatments or the wildfire. This finding was expected because of the limited number of plots exhibiting both water repellency and "relatively high" fire severities on the watersheds.

Impacts of the observed water repellency on the infiltration of water into the soil, magnitudes of the consequent overland flows, and other components of the water budgets (Ffolliott 2004) for the watersheds have not been evaluated. It is likely, however, that these impacts might be "relatively minor" because of the limited formation of water repellent soils on the watersheds.

SUMMARY

The occurrences and levels of the water repellent soils shortly after prescribed cool and warm season burning treatments and the wildfire on the Cascabel Watersheds are presented in this paper. There was little or no correlation between the limited occurrences and low levels of water repellency on the watersheds exposed to these events and the corresponding fire severities. However, the persistence of the water repellent soils on the watersheds will be monitored into the future to assess the longer-term impacts of the burning treatments and the wildfire on this soil parameter and, more generally, the hydrologic functioning of these watersheds.

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