EVAPORATION OF SOIL MOISTURE ON BURNED WATERSHEDS: AN ARIZONA CASE STUDY

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The effects of a fire on soil moisture are linked to the loss of vegetation during the combustion process which (in turn) lowers evapotranspiration losses, leaving more water in the soil than would be present in the absence of burning. Overland flow and ultimately streamflow are generally more responsive to post-fire precipitation events as a consequence of this increased soil moisture (DeBano et al. 1998; Neary et al. 2005). However, this situation does not hold true for all cases. Campbell et al. (1977) observed a reduction in soil moisture in the upper 12 inches of the limestone soil profile on a 20-acre watershed near Flagstaff, Arizona, after two-thirds of the pre-fire ponderosa pine forest overstory and much of the herbaceous understory were destroyed by a wildfire in comparison to an unburned (control) watershed. Greater overland flow on the burned watershed was the assumed factor underlying this difference. To determine whether this situation is the exception, evaporation of soil moisture on two watersheds in the ponderosa pine forests burned by the Rodeo-Chediski wildfire are compared to each other and to field capacity through three-plus years of post-fire sampling.

STUDY PROTOCOL

Two nearly homogeneous watersheds, 60 acres each, were established in 1972 by the University of Arizona and the USDA Forest Service along Stermer Ridge about 8 miles southwest of Overgaard, Arizona, to obtain baseline hydrologic and ecological information on sandstone soils (Ffolliott and Baker 1977). These watersheds possess the flat topography (most of the slopes are less than 10 percent) that is common on the Colorado Plateau. Elevations range from 6800 to 7000 feet. Beneath each watershed lies Cretaceous undivided material with mineralogy that is similar to that of the Coconino Sandstone formation. McVickers soils in the Soldier-Hogg-McVickers association characterize the watersheds. Hendricks (1985) described these moderately well to well drained soils as possessing a fine, sandy loam texture. Sixty-five percent of the annual precipitation of 20–25 inches falls from October to April, much of it as snow. The remaining precipitation falls mostly in the summer monsoonal season from July to early September. Most of the intermittent streamflow from the Stermer Ridge watersheds results from snowmelt-runoff or winter rains. The summer monsoonal storms rarely produced significant stormflows before the wildfire.

The watersheds were "mothballed" in 1977 upon completion of baseline studies. However, the control sections (3 ft H-flumes) were left in place in anticipation of future streamflow monitoring efforts. Such a need arose after the Rodeo-Chediski wildfire (Ffolliott and Neary 2003a, 2003b; Neary et al. 2003, 2005, 2006). The control sections were refurbished and re-instrumented with water-level recorders, a weather station on the site was re-established, and the permanently located sample plots established on each watershed were relocated to monitor the impacts of the Rodeo-Chediski wildfire on hydrologic and ecological processes. A classification system relating fire severity to soil response to burning (Hungerford 1996) was extrapolated to a watershed basis to determine the relative portions of the Stermer Ridge watersheds burned at low, moderate, and high fire severities (Wells et al. 1979). The extrapolation indicated that one of the Stermer Ridge watersheds experienced a high-severity, stand-replacing fire, whereas the other watershed was exposed to a low to medium-severity, stand-modifying fire.

Composited soil samples 4 inches in depth were obtained on a subsample of 15 of the 30 sample plots located on each of the watersheds. Three-plus years of post-fire samples were taken in the study; the most intensive sampling occurred in the late

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summer and autumn of 2002, after cessation of the wildlife, and throughout the growing season of 2003. Soil water in these subsamples was determined gravimetrically. The resultant drying patterns of these samples were assumed to be indicative of the magnitudes and spatial characteristics of the post-fire soil evaporation. Field capacity of the soil on unburned sites near the watersheds was determined to represent a reference in the comparisons.

RESULTS AND DISCUSSION

The results from this study differed somewhat from those obtained by Campbell et al. (1977), who reported that the loss of soil moisture on the severely burned watershed was greater than the loss of soil moisture from the unburned watershed in the 3 post-fire years of sampling in their study. While soil on the severely burned watershed dried (comparatively) quickly after the wildfire, the total demand for soil moisture by plants was less on the burned watershed than on the unburned watershed because of reduced evapotranspiration. These differences decreased, however, as a protective herbaceous cover became reestablished on the burned watershed. Conversely, soil moisture in the surface soil layers on the Stermer Ridge watershed that burned at a high severity was not different on most sampling dates than that on the watershed burned at low to moderate severity (Figure 1). One exception occurred on a sampling date in November 2002, when soil moisture on the watershed that burned at a high severity was significantly higher than that on the watershed burned at a low to moderate severity.

Seasonal differences in soil moisture were observed in 2003. Soil moisture was higher on both watersheds following the periods of snowmelt-runoff and prolonged winter rains and the summer monsoonal storms. Soil moisture was lower in the intervening dry periods. Trends for the other (less intensive) sampling periods in the study were less clear.

Soil moisture reached field capacity on two sampling dates in the autumn of 2002, within 5 months of the wildfire. That field capacity was not reached in the remainder of the study period was not surprising, however, as the three-plus years of post-fire sampling coincided with a prolonged drought period in the area.

CONCLUSIONS

Post-fire soil moisture regimes on watersheds in ponderosa pine forests on limestone (Campbell et al. 1977) and sandstone soils on the Stermer Ridge watersheds were different. Furthermore, fire severity apparently played a minor role in the post-fire soil moisture regime of the sandstone soils on Stermer Ridge. However, inferences drawn from the findings reported in this paper should be considered within the context of the infrequent post-fire sampling of soil moisture and below-average precipitation regime that persisted throughout the study period. Further monitoring of soil moisture following fire in ponderosa pine forests is suggested.

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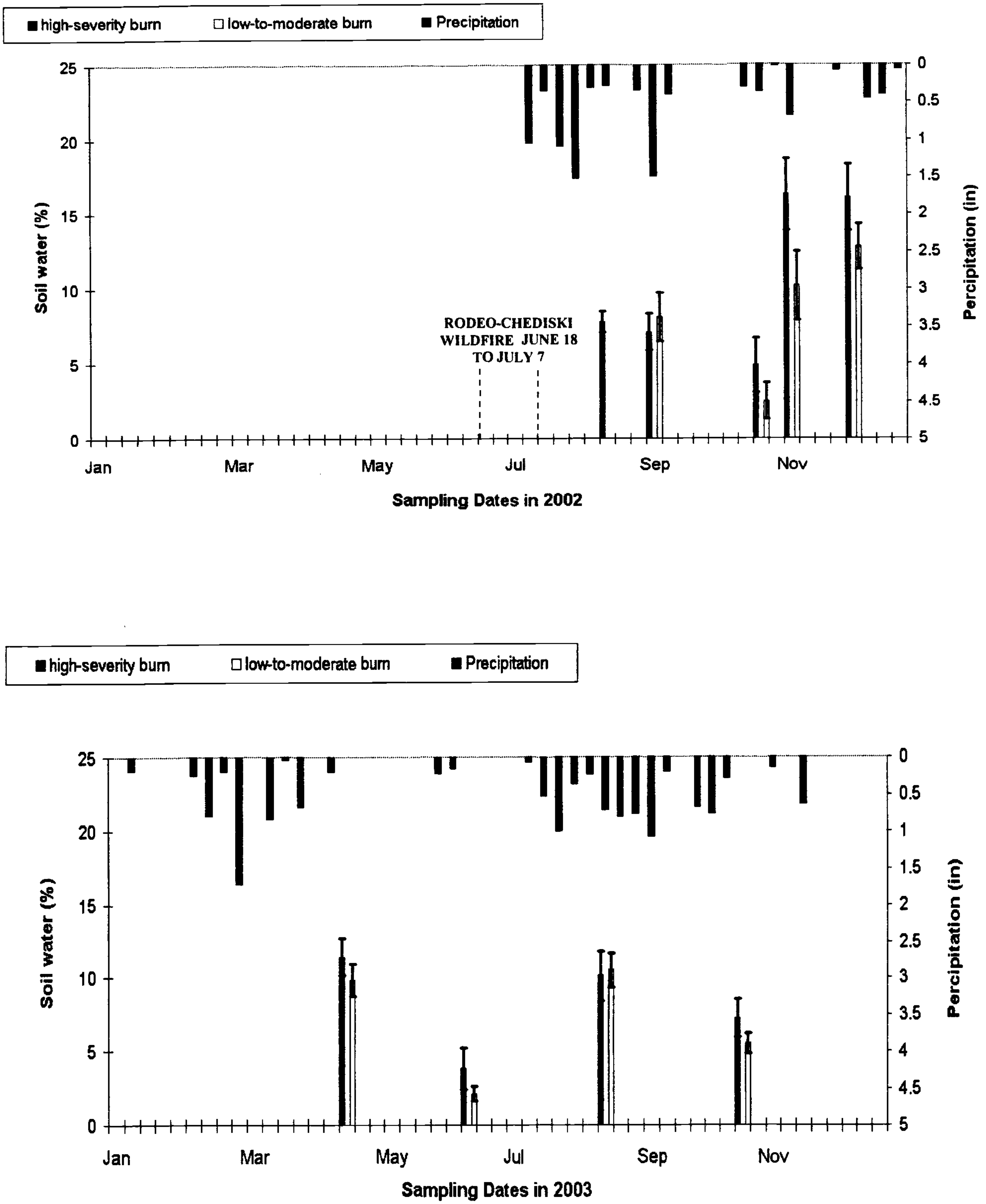

Figure 1. Average soil moisture and 90% confidence intervals (bottom) and precipitation events (top) on the Stermer Ridge watersheds for the three-plus years of post-fire sampling (continued on next page).

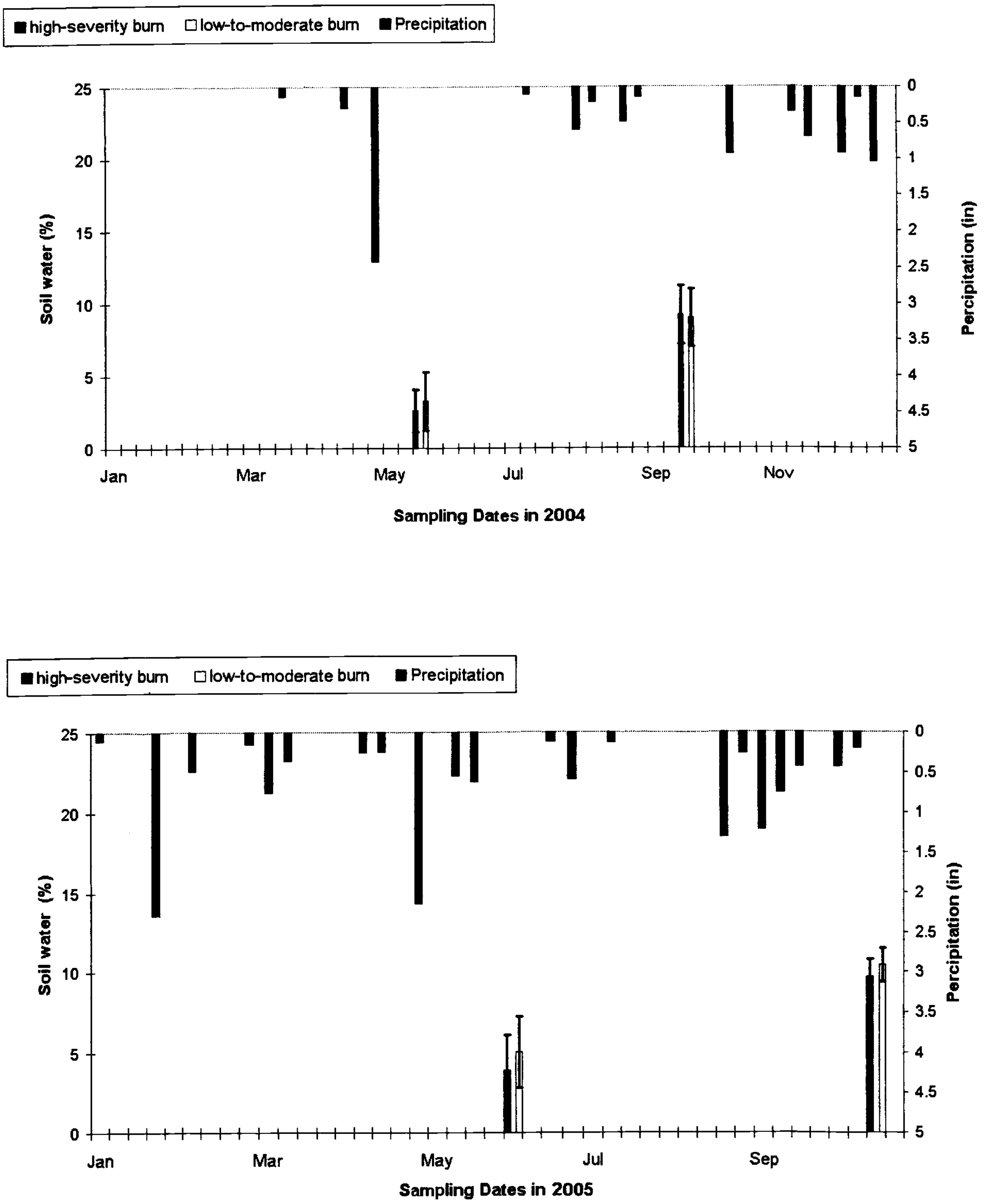

Figure 1 (continued).