Soil-Water Trends Following Wildfire on the Entiat Experimental Forest

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IN several areas of eastern Oregon and Washington soil-water contents are higher in the fall where vegetation has been removed or died than on comparable areas with more complete vegetative cover (Barrett and Youngberg, 1965; Herring, 1968, 1970; and Tarrant, 1957). The quantitative effects of the reduction in soil-water loss by evapotranspiration vary under different physiographic conditions, intensities of vegetation removal or deadening, and the kind of vegetation removed. Intense wildfire can destroy all foliar vegetation and would be expected to have the greatest impact on the autumnal soil-water deficit of any land use treatment for a particular physiographic condition.

In another presentation at this symposium, Tiedemann and Klock described the physiographic conditions of the Entiat Experimental Forest in north-central Washington swept by wildfire in August 1970. Briefly, the predominate vegetation on the Experimental Forest ranged from the mature *Pinus ponderosa/Purshia/Agropyron* habitat type in the 530- to 920-meter elevation zone to the *Pseudotsuga menziesii/Calamagrostis rubescens* habitat type (Daubenmire and Daubenmire, 1968) between 920 and 1,675 meters. Over 1,675 meters, whitebark pine (*Pinus albicaulis* Engelm.) was common.

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In most areas of the Experimental Forest all foliar vegetation was destroyed by the fire.

Soils on the Experimental Forest are entisols of the Choral and Rampart series and range from 0 to more than 6 meters deep. The upper horizons are predominantly volcanic ash and pumice and overlie decomposed granodiorite and quartz diorite. Lower sections of each drainage have remnants of glaciofluvial materials resulting from ice marginal deposits during late Pleistocene glaciation. Some glacial tills are found in scattered locations on the Forest. In areas unaffected by colluvial or alluvial movement, soil horizons exhibit the layering effect of at least six separate periods of volcanic deposition. Since each deposit is identifiable by its own rather uniform texture ranging from silt size to coarse "popcorn" pumice fragments 8-12 mm in diameter, the soil profile could be expected to show râther extreme anisotropic response to soil-water movement. Considerable horizontal movement of soil water appears to occur in the coarse-textured lower layers of the volcanic deposits.

Although maximum soil-water retention ("field capacity") does vary for each soil profile across the Experimental Forest, Figure 1 shows an average cumulative value with depth for most areas where soil depth is greater than 120 cm (curve A). Soils developed from glaciofluvial materials and glacial till have been excluded. Also shown in Figure 1 is the amount of water that appears to be lost by evapotranspiration (curve B) and the amount of water held at tensions between apparent "field capacity" (0.1 bar) and 15 bars (curve C). The large difference between the maximum and the available soil-water retention at the 90- to 160-cm zone, in contrast to that at the surface, is due to the large interpore space of the coarse-textured pumice particles in the lower depths of the soil profile (Doak, 1969).

METHODS

In early September 1970 (immediately following the fire), soil-water measurement "access" tubes were installed at the 1,280- and 1,400-m elevations in McCree watershed and the 1,500-m elevation in the Burns watershed. At each location, three tubes in a nearly equilateral triangle, approximately 4.5 m in each leg, were installed to a depth of 135 cm. Although the soil depth was greater than 135

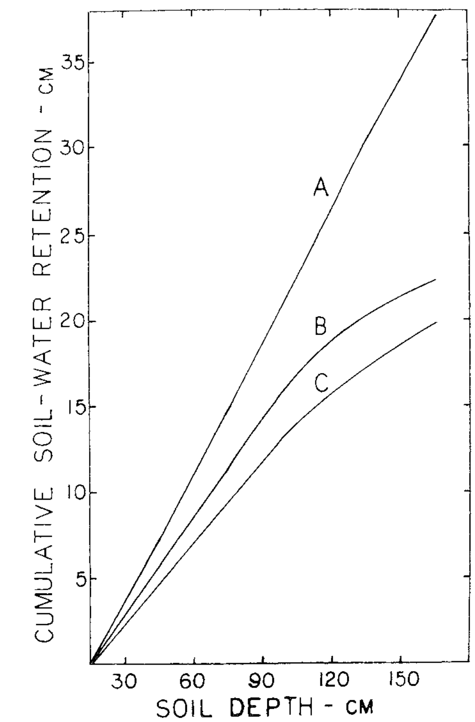

Fig. 1. Average cumulative soil-water retention with soil depth for soils on the Entiat Experimental Forest. (A) Maximum retention (B) maximum retention in the form of available water for plant use as determined from field observations, and (C) maximum retention in the form of available water for plant use between 0.1- and 15-bar soil-water suction level as determined by laboratory analyses.

cm, the tubes could not be installed deeper because the extremely dry soil profile was too unstable at the lower depth for further drilling without major disturbance. Soil-water percentages on a volume basis were measured by the nondestructive "slow-neutron" method. In 1970 no access roads existed on the watersheds. Thus, to make the soil-water measurements in 1970 and 1971, the heavy soil-water measuring equipment was back-packed a considerable distance.

In the fall of 1971, two access roads for timber salvage were constructed on the Burns and McCree watersheds. With the increased accessibility to the watersheds, soil-water measurement access tubes were installed at five additional locations in early spring 1972. All tubes were installed to the 165-cm depth and the original tubes were redrilled to 165 cm. The final tube installations were positioned to provide soil-water information on both aspects at the upper and lower elevations of Burns and McCree watersheds. The lowest elevation installation was at 1,070 m and the upper elevation at 1,610 m. No access tubes were installed in the unroaded Fox watershed. Soil-water measurements were made at 30-cm intervals of each tube on the first of the month from spring snowmelt until October 1.

A check was made in 1972 and 1973 to see if there was a distinctive difference in the minimum autumnal soil-water content between the five new and three old installations. No difference was found. Thus, we believe the three original measurement sites provided information which was a good indicator of the overall autumnal soil-water conditions on the experimental forest in 1970 and 1971.

During the 4 years in which soil water was measured, precipitation has been extremely variable. The 1970 water year (October 1, 1969, to October 1, 1970) was extremely dry, 1971 was moderate, 1972 unusually wet, and 1973 was quite dry. Precipitation levels vary considerably with elevation; thus an average precipitation value for the watershed would be too remote to use with soil-water measurements in any water budget calculation. However, all access tube locations received enough precipitation during the winter months to recharge the soil mantle to its maximum soil-water retention ability.

RESULTS AND DISCUSSION

The average cumulative soil-water depletion with increasing soil profile depth for each month of measurement, 1970-1973, is shown in Table 1. These average values are for the nine tubes used during 1970 and 1971 and the 24 tubes used in 1972 and 1973. Variation among the 24 tubes was not large. Generally the range was within ± 2 to 3 percent of the average soil-water value at each depth. Soil-water depletion values given in Table 1 are the difference between the maximum soil-water retention ("field capacity") following

TABLE 1. Cumulative soil-water depletion

Month	Depth	1970	1971	1972	1973
	cm	*cm*	*cm*	*cm*	*cm*
June	30	–	–	1.47	2.16
	60	–	–	2.54	3.91
	90	–	–	2.59	3.58
	120	–	–	2.59	4.80
	150	–	–	2.59	5.16
July	30	–	2.29	1.68	2.90
	60	–	3.71	2.79	5.05
	90	–	3.71	2.72	5.54
	120	–	4.72	3.17	6.25
	150	–	–	3.61	6.63
August	30	–	4.42	4.80	5.64
	60	–	7.06	7.87	9.96
	90	–	7.98	8.99	11.38
	120	–	8.38	9.50	11.99
	150	–	–	9.50	12.14
September	30	5.33	3.51	3.96	5.23
	60	11.33	6.15	6.76	8.97
	90	16.81	7.06	7.85	10.08
	120	19.66	8.08	8.48	10.99
	150	–	–	8.97	11.76
October	30	5.64	2.59	3.66	4.83
	60	11.63	5.84	6.88	9.14
	90	17.12	7.67	7.87	10.52
	120	20.27	8.69	8.97	11.63
	150	–	–	9.78	12.22

spring snowmelt less the actual soil water present at each measurement period. The soil-water measurement at 30 cm is considered to be an integrated value between 15 and 45 cm. Similar integrated values are assumed for 60, 90, 120, and 150 cm. The top 15 cm are ignored in the calculations since this zone is extremely variable due to surface conditions, recent precipitation, etc. Generally, evaporative conditions will dry the top 15 cm of the soil types found on the Entiat Experimental Forest within a few percent of an average depletion level regardless of the amount of vegetative cover.

Figure 2 shows the trend that autumnal soil-water deficits appear to be following since the 1970 fire. Immediately before the fire,

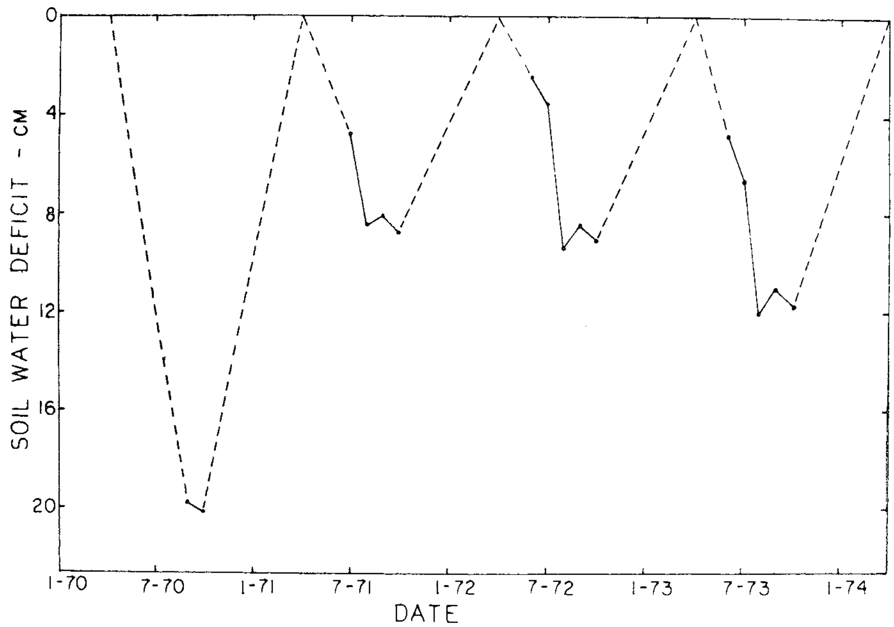

Fig. 2. Trends in the soil-water deficit in the upper 120 cm of the soil profile for 3 years following the August 1970 wildfire on the Entiat Experimental Forest.

vegetation had apparently depleted all the available soil moisture in the upper 120 cm of the soil profile. It is interesting to note that the soil-water deficit in the fall of 1970 is lower than the amount predicted as available water for plant use (maximum retention—15 bars) from laboratory analyses (Fig. 1). This indicates that soil water is available for conifers under field conditions at suction values greater than 15 bars as was shown in the laboratory by Lopushinsky and Klock (1974).

In 1971 the transpiration draft by the large conifers had been

[2]/A. R. Tiedemann and G. O. Klock. 1976. Development of vegetation after fire, reseeding, and fertilization on the Entiat Experimental Forest. Proceedings Tall Timbers Fire Ecology Conference No. 15: 171-192.

removed and the autumnal soil-water deficit was a result of surface evaporation and transpiration by the new vegetation providing the 7.5- to 10.8-percent foliar cover described by Tiedemann and Klock.[2]/ Difference between the autumnal soil-water deficit in the upper 120 cm of the soil profile from 1970 to 1971 was about 11.6 cm. This 11.6 cm of soil water would be available for streamflow in the 1972 runoff season. Certainly it was a significant part of the increased streamflow in 1972 reported by Helvey et al.[3]/ Higher than normal minimal autumn soil-water content can also be an important factor in accelerating mass soil movement on steep mountain slopes. Considerable mass soil movement was observed in 1972 in areas affected by the 1970 wildfire. Increased autumnal soil-water deficits for 1972 and 1973 appear to be the result of more evapotranspiration demand by the greater vegetative growth.[2]/

Trends for the first 3 years of vegetative regrowth appear to predict that the minimum autumnal soil-water contents will reach prefire levels in about 5 years after the fire. We do not anticipate such a quick return to prefire levels because the vegetative composition may not be similar to prefire conditions. In a nearby watershed, minimum autumnal soil-water contents for clearcut areas in a lodgepole stand have not returned to the same level as the nearby timber stand after 10 years (Herring, 1968).

We conclude that fire which removes all foliar vegetation does have an important impact on the minimum autumnal soil-water content. Higher autumnal soil-water contents caused by wildfire which reduces the evapotranspiration demand appear to make watersheds more hydrologically sensitive. The watershed buffering capacity provided by the soil mantle for unusually large precipitation events during the winter and spring months has been reduced, and streamflow becomes more responsive to precipitation input. Mass soil movement on fire-affected steep mountain slopes could also be accelerated.

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[3]/J. D. Helvey, A. R. Tiedemann, and W. B. Fowler. 1976. Some climatic and hydrologic effects of wildfire in Washington State. Proceedings Tall Timbers Fire Ecology Conference No. 15: 201-222.

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