HYDROLOGIC CHARACTERISTICS OF MIXED HARDWOOD WATERSHEDS IN THE BOSTON MOUNTAINS

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Abstract.--Precipitation and runoff were measured for 8 years and soil water for the last 3 years on four forested watersheds in the Boston Mountains of northern Arkansas. Annual precipitation averaged 1444mm and runoff 551mm. Seventy-two percent of the runoff occurred from November through April when soil water deficits were low. Runoff was highest in March and lowest in August.

Keywords: Forest hydrology, runoff, soil water, Arkansas.

INTRODUCTION

The Boston Mountains in northern Arkansas and eastern Oklahoma cover 1.4 million ha of low to moderate value forests. The forests are made up of 80 percent mixed hardwoods with the remainder primarily in shortleaf pine. Watershed and recreation values are very high. Headwaters of the White, Buffalo, Mulberry, Illinois, and Little Red Rivers and numerous tributaries of the Arkansas River originate in the forested mountainous areas, and contribute wholly or in part to five large lakes. These lakes provide flood control and hydroelectric power. Streams and rivers provide water supplies and transportation in addition to being a recreation resource.

About two-thirds of the precipitation falling on the Boston Mountains, over 820mm annually, is returned to the atmosphere as evapotranspiration. It is the major component of the water budget. Forest vegetation contributes to evapotranspiration by evaporation of intercepted precipitation from vegetative surfaces and forest litter; by evaporation from the soil surface and by transpiration from the vegetation. Soil water and runoff from forested areas are influenced by precipitation amount and intensity, type and density of vegetation, climatic conditions, soils, geology, and topography. Of these factors only type and density of vegetation and to a lesser degree surface soil conditions can be changed to alter hydrologic relationships.

This paper reports the results of an 8-year study of precipitation and runoff and a 3-year study of soil water on four watersheds that are representative of the Boston Mountains. Such data are necessary before scientists can test various management practices to determine their effects on water, timber and soil resources. This study also provides municipal, county, state, and federal water planners with information needed in determining water yields, supplies, and sewerage treatment facilities.

The four watersheds, 11.47, 13.45, 5.93, and 7.03 ha in size, are located on first-order streams in the Ozark National Forest southeast of Fayetteville,

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Arkansas, at the headwaters of the White River watershed. They have aspects ranging from west to northeast, elevations of 585 to 725m, and slopes averaging 30 percent.

The watersheds are on flat-bedded sandstone and shales and have similar topography, geology, soils, and forest cover. Soils are derived from sandstone, siltstone, and shale of the Atoka formation of the Pennsylvanian Age. Soil types are Mountainburg stony fine sandy loam and Hartsell fine sandy loam on the ridges and upper slopes; Leesburg stony fine sandy loam on the middle and lower slopes; and small scattered areas of Nella, Linker, and Enders gravelly fine sandy loams. The Mountainburg and Hartsell soils are .4 to .8m deep; Leesburg soils are 1.2 to 1.8m; and the Nella, Linker and Enders are .8 to 1.5m deep.

Vegetation on the watersheds was surveyed during the fall of 1980 and consisted primarily of red oak (Q. rubra L.), white oak (Quercus alba L.), various hickories (Carya spp.), black oak (Quercus velutina Lam.), red maple (Acer rubrum L.), and black gum (Nyssa sylvatica Marsh.). Other species encountered less frequently were black cherry (Prunus serotina Ehrh.), white ash (Fraxinus americana L.), black locust (Robinia pseudoacacia L.), Ozark chinkapin (Castanea ozarkensis Ashe), and sugar maple (Acer saccharum Marsh.). The primary understory species were dogwood (Cornus florida L.), serviceberry (Amelanchier arborea Michx.), ironwood (Ostrya virginia Mill), sassafras (Sassafras albidum Nutt.), and witch-hazel (Hamamelis virginiana L.).

Stems greater than 6.4cm d.b.h. averaged 767 per hectare on the watersheds. Forty-six percent of the stems were saplings (6.4 to 11.4cm d.b.h.), 43 percent were pole timber (11.4 to 26.7cm d.b.h.), and 11 percent were sawtimber (greater than 26.7cm d.b.h.). Basal area averaged 19.5 m^2/ha. Saplings accounted for 11 percent of the basal area, pole timber 41 percent, and sawtimber 48 percent. More than 60 percent of the stems were oaks and another 14 percent were hickories. The oaks accounted for more than 70 percent of the basal area (red, 40 percent; white, 21 percent; and black, 10 percent) and hickories 11 percent.

In the study area, summers are warm and winters moderately cold. Mean annual temperature is 15.2°C; the January average is 3.4°C, and the July average 26.4°C. Temperatures of -18°C or a little lower can occur in January and February. Average growing season is slightly over 200 days from April 5 to October 25. Longterm average annual precipitation is 1270mm. Precipitation is distributed fairly evenly throughout the year, although the growing season averages over 800mm. Most precipitation is rain, but light snow normally falls a few times each year. Evapotranspiration--the sum of evaporation of intercepted precipitation, evaporation from the soil surface, and transpiration from vegetation--averages about 860mm annually on the watersheds. Annual evapotranspiration as calculated by the Thornthwaite and Mather (1957) method was 810mm or 50mm less than found on the study watersheds. Their lower evapotranspiration value was due to lower levels of calculated evapotranspiration during the October through March period.

METHODS

From 1973 through 1980, the amount of storm precipitation was determined by averaging values obtained from standard gages at the top and bottom of the watersheds.

During the same 8-year period, runoff from each of the four watersheds was

measured in a 3-foot H-flume. Stage, or depth of water in the flume, was recorded with FW-1 water level recorders and converted to area-millimeters per storm.

In the spring of 1978, 32 soil water access wells were allocated proportionally by watershed size and within watersheds by soil type. Wells were spaced to obtain a good distribution over the watersheds and were installed to a depth of 180cm or to a lesser depth if bedrock was encountered. Soil water was measured with a neutron probe system 10cm beneath the soil surface and at subsequent 20cm intervals to the bottom of the wells. Measurements were made at approximately 2-week intervals during the March through November period for 1978-1980. Soil water values reported here are averages from the four watersheds.

RESULTS AND DISCUSSION

Precipitation and Runoff

Annual precipitation ranged from 924mm in 1980 to 2167mm in 1973 and averaged 1444mm, or about 170mm more than the longterm mean (USDA, 1941) for the area (Table 1). Precipitation was fairly evenly distributed throughout the year, but January and February means were somewhat lower and March and September were somewhat higher than those for the other months (Table 2).

Annual runoff ranged from 206mm in 1980 to 1143mm in 1973 when precipitation was 2167mm (Table 1). Average runoff for the 8 years was 551mm, or 38.2 percent of the average annual precipitation. This percentage is similar to the 43.7 percent found on watersheds in West Virginia (Reinhart et al. 1963).

Runoff occurred nearly every month of the study. Only the months of August and October in two of the drier years had no runoff. Mean runoff was highest in March and lowest in August (Table 2). Seventy-three percent of the annual runoff occurred during the November through April dormant season. Low runoff during the May through October growing season, when 52 percent of the annual precipitation fell, is attributed to high evapotranspirational losses associated with forest vegetation. This is very similar to results from a watershed study in the Ouachita Mountains of central Arkansas (Rogerson 1971).

The amount of precipitation needed to initiate a runoff event varied from about 12mm to 40mm, depending primarily on the amount of water in the soil. Peak discharges greater than 0.1 m^3/s occurred an average of 1.25 times per year. These discharges usually occurred during the November through April period and were associated with rainfall in excess of 75mm and nearly saturated soil conditions.

Soil Water

Mean soil water content on the watersheds reached a high of 414mm on April 12, 1979. This total is slightly higher than the estimated field capacity of 390mm. The lowest mean soil water recorded was 242mm on October 31, 1978. Thus, available soil water storage is about 170mm.

Soil water deficits (difference between current water content and recorded maximum) usually ranged from near 0 to 50mm from November through May when evapotranspiration was low (Figure 1). Eighty-four percent of the annual runoff from the watersheds occurred during this period. From June through October, when

Table 1.--Annual precipitation and mean runoff for Fleming Creek watersheds, 1973-1980.

Year	Precipitation	Runoff Watershed 1	2	3	4	Mean
	mm					
1973	2167	1221	1186	1192	973	1143
1974	1824	996	926	812	737	868
1975	1366	584	497	432	376	472
1976	1070	313	244	150	183	222
1977	1441	511	439	374	341	416
1978	1305	528	484	435	384	458
1979	1451	677	707	591	511	622
1980	924	280	216	155	171	206
Mean	1444	639	587	518	460	551

Table 2.--Monthly mean and range precipitation and runoff for Fleming Creek Watersheds, 1973-1980

Month	Precipitation Range	Precipitation Mean	Runoff Range	Runoff Mean
	-mm-		-mm-	
January	20 - 160	71	4 - 90	29
February	32 - 129	66	9 - 104	49
March	78 - 360	179	45 - 259	136
April	53 - 297	125	17 - 247	80
May	71 - 232	151	2 - 144	63
June	66 - 251	149	1 - 193	51
July	27 - 231	96	T 1/ - 14	3
August	19 - 287	92	0 - 6	1
September	31 - 357	171	T 1/ - 178	25
October	20 - 202	97	0 - 47	8
November	52 - 292	155	1 - 208	61
December	43 - 152	92	4 - 104	45
Annual	924 - 2167	1444	206 - 1143	551

1/ T = Trace (Less than 0.02mm)

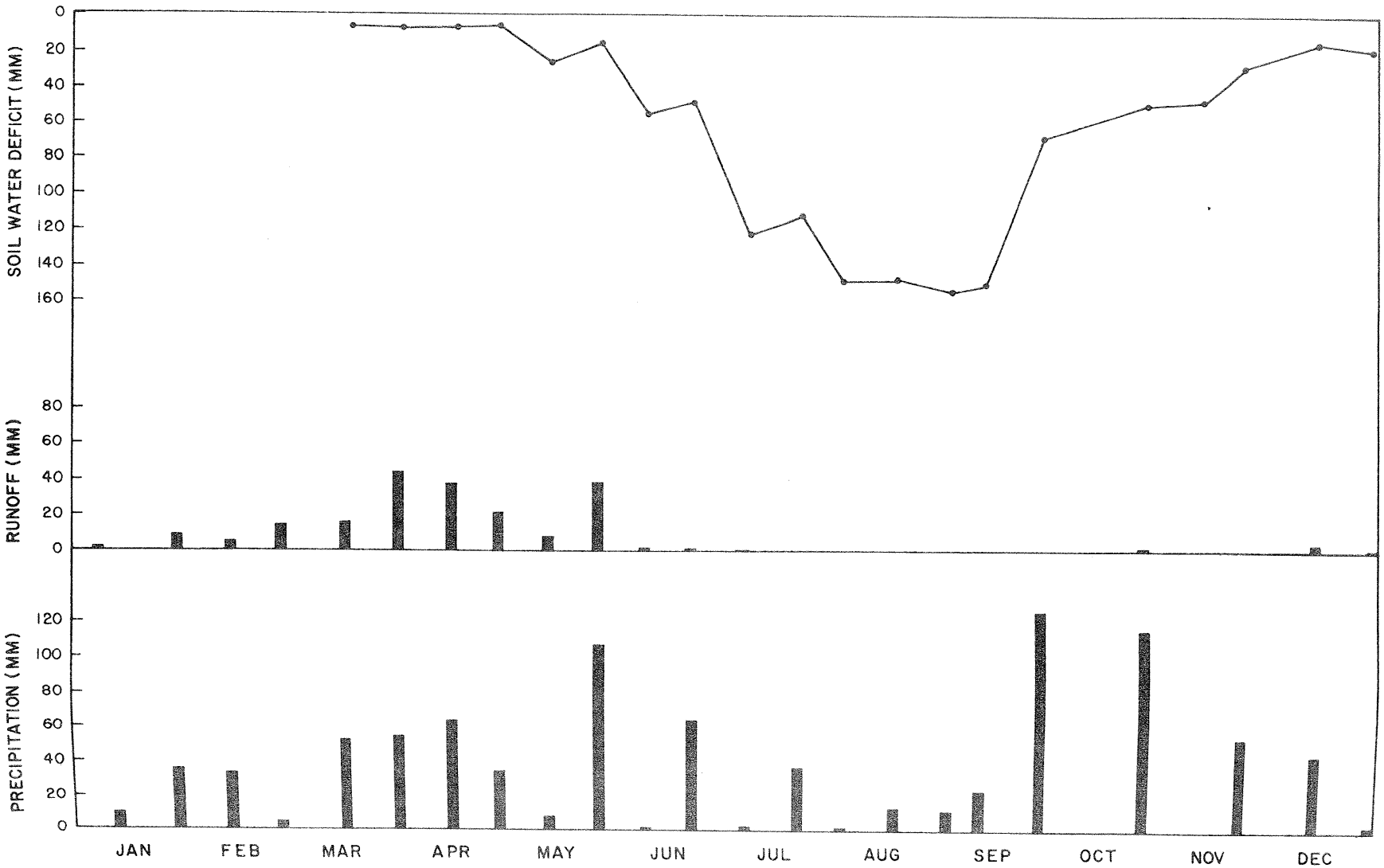

Figure 1.--Precipitation, runoff, and soil water deficits for Fleming Creek watersheds during 1980 show seasonal trends typical of the entire study period.

evapotranspiration levels are high, soil water deficits increased rapidly. Infrequent, large summer storms of short duration temporarily reduced the surface soil water deficits and produced small amounts of runoff. Deficits reached 130 to 170mm in August through October before precipitation and lower evapotranspiration enabled soil water recharge to take place.

Seasonal changes in evapotranspiration rather than in precipitation are the major cause of large soil water deficits and low runoff in summer and fall. Evapotranspiration can be reduced and streamflow increased by removing 20 percent or more of the vegetation from a watershed (Douglass 1967). As part of a continuing study of hydrologic response to management practices, one watershed will be thinned, another clearcut, and another converted to pine. The effects of these treatments on soil water, runoff, sediment and nutrient losses, and vegetative growth and changes will be observed and compared with an untreated control watershed.

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