HYDROLOGIC CHARACTERISTICS OF MIXED HARDWOOD CATCHMENTS IN THE OZARK PLATEAU

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Precipitation, runoff, and sediment losses were measured for 10 years and soil water for the last 6 years on three small forested catchments in the Ozark Plateau in northern Arkansas. Annual precipitation averaged 46.5 inches; runoff, 2.2 inches; and sediment losses, 19.7 pounds per acre. Eighty-seven percent of the runoff occurred during November through April, when soil water deficits were low. Runoff was highest in December and lowest in August and September, when soil water deficits were large because of evapotranspiration.

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INTRODUCTION

The Ozark Plateau in southern Missouri and northern Arkansas covers about 26.5 million acres, 11.4 million acres of which are commercial forests consisting mainly of oak species. Streamflow from these forests is the major water source for a growing population, for a rapidly expanding recreation business, and for other industries in the region. However, streamflow is often marginal during July through October, when demand for water is highest.

This paper reports the results of a 10-year study of precipitation, runoff, and sediment losses on three catchments that are representative of the Ozark Plateau. Such data are essential before foresters can test management practices that might increase streamflow during summer and fall.

STUDY AREA

The three adjoining catchments, 5.17, 5.76, and 4.29 acres in size, are located on the Koen Experimental Forest south of Harrison, Arkansas, in the Buffalo River watershed. They have aspects ranging from south to west, elevations of 1,010 to 1,220 feet, and slopes averaging 30 percent. The catchments, located in karst terrane, have similar topography, geology, soils, and forest cover. Soil types are Baxter cherty silt loam on upper slopes, Clarksville and Colbert cherty silt loams on the mid-slopes, and Gasconade stony silty clay loam on the lower drainages. Soils are

derived from the Boone limestone formation of the Mississippian period. The Baxter and Clarksville soils are 5 to 6 feet deep, well drained, and moderately permeable. The Colbert soils are 4 to 5 feet deep with fair to poor drainage and slow permeability. The Gasconade soils are shallow (2 to 3 feet deep), well to excessively well drained, have moderate to slow permeability, and drainage follows cracks and crevices. Caves, sinkholes, and wet weather springs are common in the general area.

Vegetation on the catchments was surveyed in 1972 and consisted primarily of white oak (*Quercus alba* L.), red oak (*Q. rubra* L.), southern red oak (*Q. falcata* Michx.), black oak (*Q. velutina* Lam.), various hickories (*Carya* spp.), white ash (*Fraxinus americana* L.), shortleaf pine (*Pinus echinata* Mill.), and eastern red cedar (*Juniperus virginiana* L.). Other species encountered less frequently were various elms (*Ulmus* spp.), black walnut (*Juglans nigra* L.), and black cherry (*Prunus serotina* Ehrh.). The primary understory species were dogwood (*Cornus florida* L.), ironwood (*Ostrya virginiana* Mill.), and huckleberry (*Vaccinium* spp.).

Stems greater than 2.5 inches d.b.h. averaged 338 per acre on the three catchments. Fifty percent of the stems were saplings (2.5 to 4.5 inches d.b.h.), 38 percent were pole timber (4.5 to 10.5 inches d.b.h.), and 12 percent were sawtimber (greater than 10.5 inches d.b.h.). Basal area averaged 91.0 ft^2/acre. Saplings accounted for 12 percent of the basal area, pole timber 37 percent, and sawtimber 51 percent. Over half the stems were oaks, and they accounted for nearly two-thirds of the basal area.

In the study area, summers are warm and winters are moderately cold. Mean annual temperature is 58.3°F; the January average is 38.6°, and the July average is 78.6°. Temperatures of 0°F or slightly less can occur in January and February. Average growing season is about 190 days from April 15 to October 22. Long-term average annual precipitation is 45 inches. Precipitation is distributed fairly evenly throughout the year, although May and June have slightly greater and December and January slightly lesser amounts than the other months. Almost all 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 32 inches annually on the catchments, as calculated by the Thornthwaite and Mather (1957) method.

METHODS

From 1965 through 1974, the amount of storm precipitation was determined by averaging values obtained with a standard gage at the top of the catchment complex and one at its base. Five- and 15-minute rainfall intensities and storm duration were determined from a recording gage at the top of the catchment complex.

During the same 10-year period, runoff from each catchment was measured in a 2-foot H-flume. Stage, or depth of water in the flumes, was recorded with FW-1 water level recorders and converted to area-inches per storm. Suspended sediment in runoff was sampled with Coshocton samplers and filtering devices (Blocker and Bower 1963). The samplers were set to begin sampling at a stage of 0.12 ft. (0.034 ft^3/s) because lower stages contain very little sediment. Total sediment deposited in the flumes and approach basins during runoff events was weighed in the field; then samples were taken to determine ovendry weight. Sediment losses reported in this paper are the ovendry weight of both suspended and deposited materials.

In April 1969, 24 soil water access wells were allocated proportionately by catchment size and within catchments by soil type. Wells were spaced to obtain a good distribution over the catchments and were drilled to a depth of 72 inches or to a lesser depth if bedrock was encountered. Soil water was measured with a neutron probe system 9 inches beneath the soil surface and at subsequent 6-inch intervals to the bottom of the wells. Measurements were made at approximately 2-week intervals through December 1974, and soil water content in the 6- to 66-inch depth was averaged for the three catchments.

RESULTS AND DISCUSSION

Precipitation and Runoff

Annual precipitation ranged from 31.71 inches in 1966 to 74.81 inches in 1973 and averaged 46.47 inches, or about 1.5 inches more than the long-term mean (Table 1). Precipitation was fairly evenly distributed throughout the year, but January and February averages were somewhat lower and April, September and December averages were somewhat higher than those for the other months (Table 2).

Annual runoff ranged from 0.44 inch in 1972 to 8.96 inches in 1973, when precipitation was 74.81 inches (Table 1). The average for the 10 years was 2.16 inches, or 4.6 percent of the average annual precipitation. This percentage is low when compared to the 10 to 40 percent reported for other areas (Reinhart et al. 1963, Ursic 1970, Rogerson 1971). The low runoff may be due to small catchment size and to underground drainage past the flumes through the karst terrane. Such underground drainage has been observed from other catchments in the same general area.

Runoff occurred in every month at least once during the study. Mean runoff was highest in December and lowest in August and September (Table 2). Eighty-seven percent of the annual runoff occurred during the November through April dormant season. Low runoff in May through October, when 51 percent of the annual precipitation fell, is attributed to high evapotranspirational losses associated with forest vegetation.

Table 1. Annual precipitation and mean runoff for Koen catchments, 1965-1974.

Year	Precipitation (Inches)	Runoff (Area-inches)
1965	46.39	1.16
1966	31.71	1.62
1967	46.36	0.81
1968	54.38	2.38
1969	38.90	2.03
1970	46.01	0.74
1971	40.92	1.82
1972	37.52	0.44
1973	74.81	8.96
1974	47.73	1.65
Mean	46.47	2.16

Table 2. Monthly range and mean precipitation and mean runoff for Koen catchments, 1965-1974.

Month	Precipitation		Runoff Mean (Area-inches)
	Range	Mean	
	----------Inches--------		
January	1.07 - 5.58	2.42	0.16
February	0.81 - 5.15	2.40	0.14
March	0.98 -12.22	3.50	0.39
April	2.43 -11.04	5.28	0.44
May	1.98 - 6.55	4.39	0.08
June	0.82 - 6.41	4.12	0.14
July	0.41 - 5.87	3.17	0.03
August	1.42 - 5.14	2.93	0 1/
September	2.44 - 8.21	4.93	0 1/
October	0.76 - 8.17	4.26	0.03
November	0.76 -10.24	4.18	0.27
December	1.09 -10.82	4.89	0.48
Annual	31.71 -74.81	46.47	2.16

1/ Mean is less than 0.003 inch

The amount of precipitation needed to initiate runoff varied from about 0.8 inch to over 3.0 inches, depending primarily on amount of water in the soil and to a lesser degree on precipitation intensity. Peak discharges greater than 1.0 ft^3/s occurred an average of 1.1 times per year and were usually preceded by rainfall in excess of 2.5 inches and 15-minute intensities greater than 1.4 inches per hour. A maximum discharge of 4.28 ft^3/s was recorded for catchment 2 on November 23 and 24, 1973. On these dates 6.67 inches of rain was measured in 28.5 hours, and the 15-minute intensity was 2.54 inches per hour.

Sediment

Sediment losses from the study catchments have been small, averaging only 19.7 pounds per acre per year during the 1966-1974 period. In contrast, annual sediment losses of 200 pounds per acre were reported for hardwood watersheds in northern Mississippi (Ursic 1970); in North Carolina losses were 154 pounds per acre when the watershed supported hardwoods and 1 ton per acre when it was farmed (Dils 1953). Average annual losses ranged from 64.4 pounds in 1973 to 1.9 pounds per acre in 1972. This large range is attributed to differences in storm frequency, size, and intensity, which influence soil water content and runoff discharge rates. Large storms periodically flush out drainage channels and produce larger than normal sediment losses. Discharge rates greater than 0.50 ft^3/s occurred in only 24 percent of the runoff-producing storms, but these storms accounted for 91 percent of the sediment losses.

Soil Water

Mean soil water content in the 6- to 66-inch depth reached a high of 21.7 inches on April 18, 1969. This total is roughly 0.8 inch greater than the estimated field capacity of 20.9 inches. The lowest mean soil water recorded was 9.8 inches on September 12, 1972. Thus, potential storage for available water is about 11 inches.

Soil water deficits (difference between current soil water content and recorded maximum) usually ranged from 0 to 3 inches from November through early June, when evapotranspiration was low (Figure 1). Nearly all runoff from the catchments occurred during this period. From mid-June through October, when maximum evapotranspiration occurs, soil water deficits increased rapidly. Infrequent large summer storms of high intensity temporarily reduced the surface soil water deficits and produced small amounts of runoff. Deficits reached 9.6 to 11.9 inches in August through October before precipitation and lower evapotranspiration enabled soil water recharge to take place.

If streamflow in the Ozark Plateau is to be increased, methods must be found to lower soil water deficits during the growing season. Seasonal changes in evapotranspiration rather than in rainfall are the major cause of large soil water deficits and limited runoff in summer and fall. Evapotranspiration probably can be reduced and streamflow increased by removing

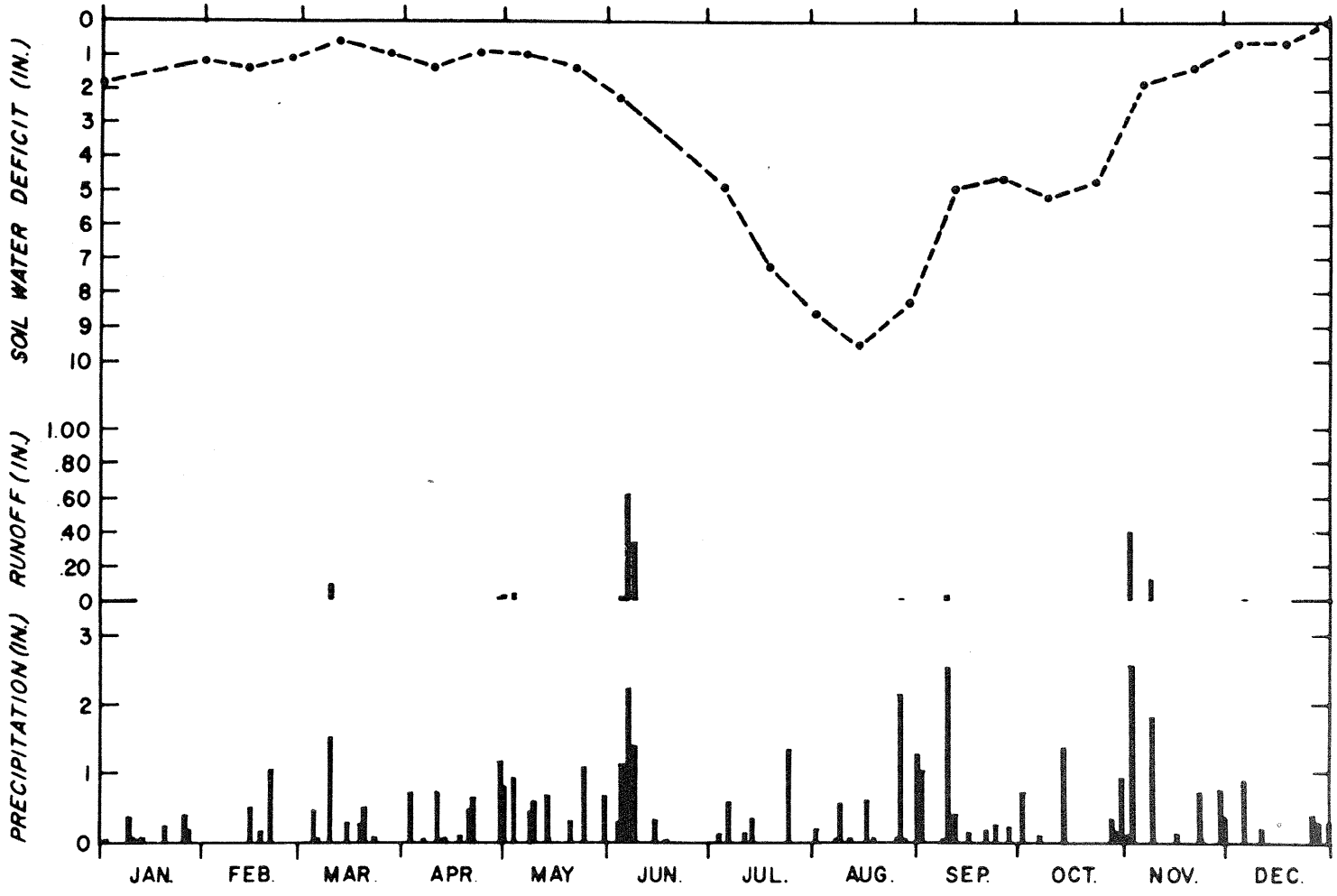

Figure 1. Precipitation, runoff, and deficits from maximum soil water for Koen catchments in 1974 show seasonal trends typical of the entire study period.

20 percent or more of the vegetation from a watershed (Douglass 1967). Clearcutting lowered average growing season deficits by 5 inches in northern Arkansas (Rogerson, unpublished data). Timber stands on the study catchments are to be thinned to different levels of stand density, and the effects of these treatments on soil water, runoff, and sediment production will be observed.

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