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WINTER PRECIPITATION ON A SOUTHEASTERN ARIZONA RANGELAND WATERSHED[1]

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INTRODUCTION

A principal research effort on the USDA Walnut Gulch experimental watershed in southeastern Arizona (Fig. 1) has been to identify and quantify rainfall and runoff from summer convective storms (Osborn and Renard, 1970; Osborn and Laursen, 1973). A dense network of over 90 recording raingages (Fig. 2) has been installed for this purpose (Renard, 1970). However, winter precipitation as rain or snow is an important source of rangeland moisture for spring growth of many species of grasses, shrubs, and forbs that are grazed by livestock. The growth of many of these species is controlled by the amount and timing of winter precipitation (Cable and Martin, 1975).

In this paper, winter precipitation data from selected Walnut Gulch gages were analyzed using varying durations and gage spacing. The effects of elevation were investigated. Also, the long term precipitation record for Tombstone, centrally located on the Walnut Gulch watershed, was analyzed for intercorrelations of seasonal precipitation, trends, representativeness of the shorter Walnut Gulch record, and occurrence of maximums and minimums within the long term record.

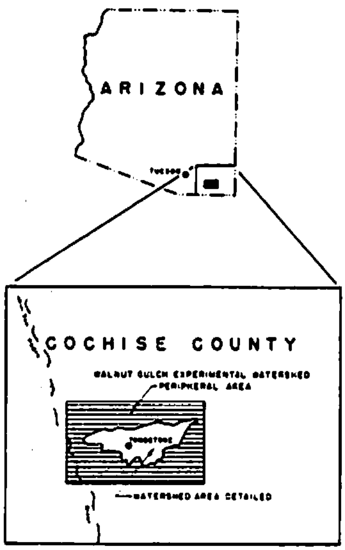

Figure 1. Location of Walnut Gulch Watershed.

WINTER PRECIPITATION

Annual precipitation data were divided by season -- winter and summer. Winter includes the months of November and December of one year, and January through March of the next year. Winter precipitation in the area is characterized by long duration, low intensity, frontal storms covering large areas (Sellers, 1960). Figure 2 is an isohyetal map of 1965-1966 winter season precipitation. December and January are the wettest winter months, and March is the driest. Less than 10% of winter precipitation is snowfall. Summer precipitation includes May through September. It is usually of short duration, high intensity, and limited areal extent (Sellers, 1960; Osborn and Reynolds, 1963). July and August are the wettest months, and May the driest (Table 1).

Table 1. Monthly and seasonal precipitation amounts for Tombstone, AZ (1904-1978) (mm).

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
	4.8	12.2	93.2	87.9	37.3	19.3	16.3	20.8	20.1	19.6	16.0	6.9
Seasonal Mean	235.5					19.3	92.7					6.9
Range	110.0-419.6					0-90.2	19.3-287.5					0-45.0

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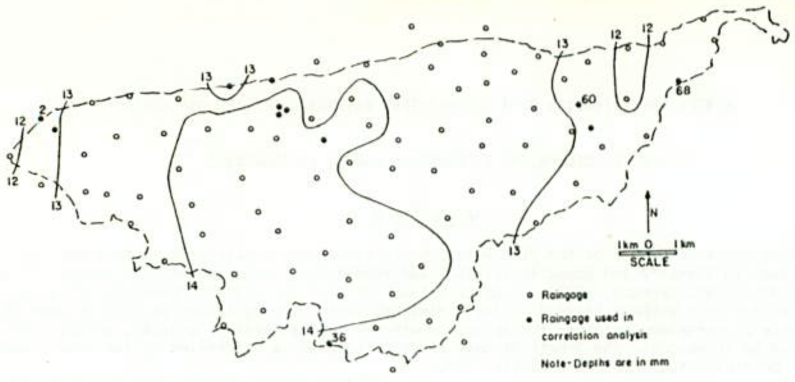

Figure 2. Raingage network and typical winter precipitation pattern (mm) at Walnut Gulch.

Walnut Gulch

Raingage spacing for representative sampling has been shown to be critical for summer precipitation in areas where thunderstorms are dominant. Osborn, Lane, and Myers (1979) showed that for storm rainfall, correlation coefficients (r) between gages dropped below 0.9 at a distance of around 1 km; thus, a dense network of gages is needed to quantify storm precipitation. A similar study was initiated to determine necessary spacing for winter storms. Correlation coefficients between gages for winter precipitation were determined for pairs of 9 selected gages for 1-hr, 6-hr, 24-hr, and seasonal depths. The relationships between correlation and distance are shown in Fig. 3-4. The relationship between gages for 1-hr depths (Fig. 3) is difficult to define. The most likely explanation is that, since many of the winter precipitation amounts are quite small, errors in measurement become relatively large. The correlation for 6-hr precipitation (Fig. 4) is better defined, indicating a rapid drop in correlation up to about 1 km, with the curve relatively flatter thereafter. The relationship for 24-hr depths suggests a steady decay in correlation with distance. For seasonal estimates, one gage on the 150-km^2 watershed probably would be satisfactory. All curves were fitted by eye. The 6-hr, 24-hr, and seasonal curves for winter events are compared directly with summer curves for the same durations (Fig. 4). All winter event curves are significantly higher than their summer counterparts.

Four Walnut Gulch gages at different elevations were selected for an analysis of elevation effects on winter precipitation depths. The maximum 1-, 6-, and 24-hr, 100-yr winter storms were predicted from 20 yrs of record at these gages using the Gumbel extreme value procedure (Gumbel,1958)(Table 2). There

Table 2. 100-yr, 1-, 6-, and 24-hr winter precipitation amounts for four selected gages on Walnut Gulch.

Gage (elevation)		2	36	60	68
Duration	Statistic	(1261 m)	(1466 m)	(1522 m)	(1580 m)
		(mm)			
1-hr					
	$\bar{X}$	5.0	5.1	5.0	4.6
	S	2.4	2.9	2.6	2.4
	100-yr	14.2	16.5	15.0	14.0
6-hr					
	$\bar{X}$	11.9	11.9	10.7	10.2
	S	4.8	4.6	3.0	3.6
	100-yr	30.2	30.0	22.4	23.9

Table 2. (Continued).

Duration	Statistic	2 (1261 m)	36 (1466 m)	60 (1522 m)	68 (1580 m)
			Gage (elevation) - - - - (mm) - - - -		
24-hr					
	$\bar{X}$	19.1	18.0	16.5	16.3
	S	8.6	6.4	5.3	3.8
	100-yr	53.1	42.4	37.1	31.5

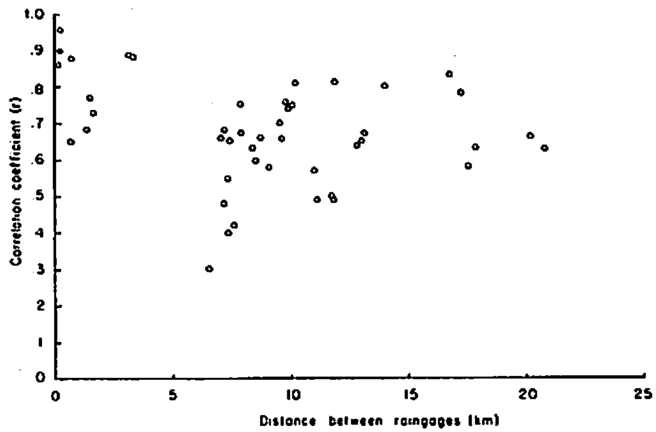

Figure 3. Correlation between gages and distance for 1-hr rainfall depths for winter precipitation on Walnut Gulch.

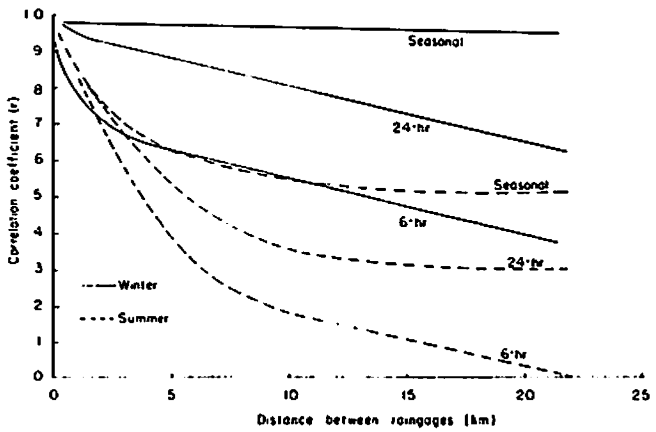

Figure 4. Correlation between gages and distance for 6-hr, 24-hr, and seasonal rainfall depths for winter and summer precipitation at Walnut Gulch.

were no significant differences in 1-hr, 100-yr values among the four stations. There was some indication of a decrease with increasing elevation for the 6-hr predictions, and a significant decrease with increasing elevation for the 24-hr predictions. In the Gumbel distribution, predictions are influenced by variance, and the variance was less at higher elevations. This could be misleading. However, mean values also decreased with increasing elevation. At the least, we have no evidence that extreme events have greater depths at higher elevations. Also, similar tests of summer total storm rainfall amounts indicated no increase with increasing elevation.

Tombstone

Cooperative National Weather Service daily rainfall records have been kept for Tombstone since the early 1890's. However, in early years, the record was irregular, and only 75 yrs of data (1904-1978) were used in this study. During the period, summer and winter precipitation were 66% and 26%, respectively, of annual precipitation, with April and October rainfall 8% of the annual mean. Annual summer rainfall ranged from 110 to 420 mm, whereas annual winter rainfall precipitation ranged from 20 to 290 mm. Five-year moving means of summer, winter, and annual precipitation are shown in Fig. 5 (dashed lines from 1904 through 1907 represent means of less than 5 yrs). Partial records before 1904 suggest heavy winter precipitation around 1900, with 1904-1905 the last winter of a reported "wet" period. Winter precipitation in 1904-1905 was 290 mm, which is the largest during the record period. The moving mean for winter precipitation was well above average in the middle 1910's, slightly above average in the 1930's, and has been below average since 1942. Since 1942, about 1/3 of the winter seasons have been above average (although none exceptionally high), but not for enough consecutive years to raise the moving mean above the average. In contrast, moving means for summer and annual precipitation were above average as recently as the late 1950's and have been below average since 1961.

Intensive studies were initiated on small Walnut Gulch watersheds and plots in 1962, and moving means for winter, summer, and annual precipitation have been below average since then. However, just over 150 mm of winter precipitation were recorded in 1977-78, which was the highest since 1919.

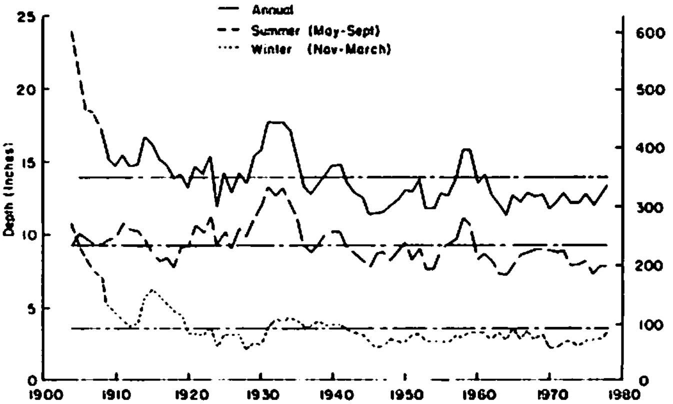

Figure 5. Five-year moving means for seasonal and annual rainfall for Tombstone, Arizona (1904-1908).

Correlation coefficients (r) among seasonal precipitation amounts for Tombstone (1904-1978) are shown in Tables 3 and 4. In Table 3, winter follows summer; in Table 4, summer follows winter. The underlined values are within the 95% confidence limits for random selection, and indicate that predicting either summer from winter or winter from summer precipitation is impossible. Also, there is no suggestion of serial correlation (summer, r = .05; winter, r = .17, and annual, r = .06) from year to year, although wetter and drier periods are indicated by the running means.

Table 3. Correlation coefficients (r) among seasonal precipitation amounts for Tombstone (1904-1978); winter follows summer.*

	Summer	October	Winter	April	Annual
Summer	1.0	.01	.09	-.02	.62
October		1.0	.30	.02	.22
Winter			1.0	.28	.44
April				1.0	.16
Annual					1.0

*Underlined values are within random error of selection.

Table 4. Correlation coefficients (r) among seasonal precipitation amounts for Tombstone (1904-1978); summer follows winter.*

	Summer	October	Winter	April	Annual
Summer	1.0	.01	-.12	-.11	.73
October		1.0	-.04	-.05	.22
Winter			1.0	.29	.54
April				1.0	.19
Annual					1.0

*Underlined values are within random error of selection.

OBSERVATIONS

Annual winter precipitation seems to be at least as variable from year to year as summer precipitation. Because of the larger areal extent of most winter storms, one raingage probably could be used to give an accurate estimate of annual winter precipitation on the 150 km^2 Walnut Gulch experimental watershed. The data are not as clear cut for winter storm analysis, but we did decide that a well-spaced 8-gage network plus several gages at locations where we were carrying out intensive studies on very small areas would be satisfactory (Fig. 2). Part of our decision, however, was because there have been very few runoff-producing winter storms on Walnut Gulch.

Analysis of gage correlation versus elevation suggested a possible decrease in precipitation with increasing elevation for major winter events. However, a range of 320 m in elevation may be insignificant as compared with other climatic and topographic features.

The moving means for both summer and winter precipitation have remained below average since 1962, when our intensive small watershed and plot studies were initiated. Several "lows" have been recorded since 1962, but no "highs." Low winter precipitation probably has increased the stress on palatable spring-grazed vegetation and further improved the chances for survival of more deep-rooted unpalatable shrubs. Studies carried out since 1962 are biased by the lower average seasonal precipitation, but only a sustained "wet period" will allow us to determine just how biased.

SUMMARY

Twenty years of winter precipitation data from the Walnut Gulch experimental watershed were analyzed. Winter precipitation varied widely over the watershed for storm durations up to 6 hr, indicating that a network of gages, rather than a single gage, might be needed for winter as well as summer storms. However, 24-hr and seasonal precipitation among raingages were highly correlated, indicating that 1 raingage on the 150 km^2 watershed probably would give a fairly accurate estimate of winter precipitation.

When 100-yr return frequencies for Walnut Gulch winter precipitation were plotted against elevation, 1-hr duration depths showed no trend, but 6- and 24hr storm totals suggested a decrease with increasing elevation.

A 5-yr moving mean, based on 75 yr of record at Tombstone, Arizona (located on the Walnut Gulch watershed), showed the variability of winter, summer, and annual precipitation from year to year as well as major periods of above and below average precipitation. This moving mean also indicated that both mean summer and mean winter precipitation have remained below average since 1962, when our intensive small watershed and plot studies were initiated.

There was no evidence of correlation between summer and winter precipitation. However, there was a good correlation between summer and annual precipitation, and a weaker correlation between winter and annual precipitation. There was no significant serial correlation between consecutive years of summer or winter precipitation.

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