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DISTRIBUTION OF SUMMER RAINFALL DEFICITS ON A SOUTHWEST RANGELAND WATERSHED

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In southeastern Arizona, summer precipitation is the principal and most reliable source of rangeland moisture (Osborn, 1968). Summer storms are convective, short-lived events of limited areal extent. Within a watershed, rainfall varies both seasonally and annually, as well as spatially. Warm season range vegetation must take advantage of summer rainfall following a hot, dry spring. The amount of summer rainfall that is critical to the survival of range vegetation is considerably below the long-term average. Local rainfall deficits can occur within a season which is designated as average or above average over the region. Identifying the probability of local rainfall deficits is particularly important in evaluating range management and renovation efforts such as grazing rotation and revegetation. In this paper, a proposed non-parametric method (Robinson and Fesperman, 1986) was used to investigate the pattern of summer rainfall deficits within a 58-sq-mi rangeland watershed in southeastern Arizona.

WATERSHED DESCRIPTION

The 58-sq-mi Walnut Gulch Experimental Rangeland Watershed in southeastern Arizona (Figure 1) is representative of millions of acres of brush and warm-season rangeland found throughout the semiarid southwest and is considered a transition zone between the Chihuahuan and Sonoran Deserts (Hastings and Turner, 1965). The Pacific Ocean is the major source of summer rainfall in southeastern Arizona, with the Gulf of Mexico a secondary source (Hales, 1973; Osborn and Davis, 1977). Major thunderstorms occur when substantial moist tropical air flows into Arizona from the south and southwest. Average annual precipitation on the watershed is about 11.5 inches and is bimodally distributed with 70% occurring during the summer thunderstorm season from late June to mid September and the remaining 30% occurring as frontal winter storms. There are no significant positive or negative correlations between sea sonal or annual precipitation totals (Osborn, 1983).

METHODS

Robinson and Fesperman (1986) used a method of conditional probabilities for adjacent raingage stations to look for patterns of seasonal and annual precipitation deficits in North Carolina. They found this simple non-parametric test useful for identifying areas within the State prone to drought. They considered North Carolina as a small, or mesoscale, area. The dominance of convective storms in the Southwest suggested that such a procedure might apply to much smaller areas such as the Walnut Gulch Watershed, at least for summer rainfall.

The study was based on records from 38 weighing-type recording raingages for the summers of 1956 through 1977 (Fig. 1). Although the present network consists of 90 recording raingages, only 38 were in

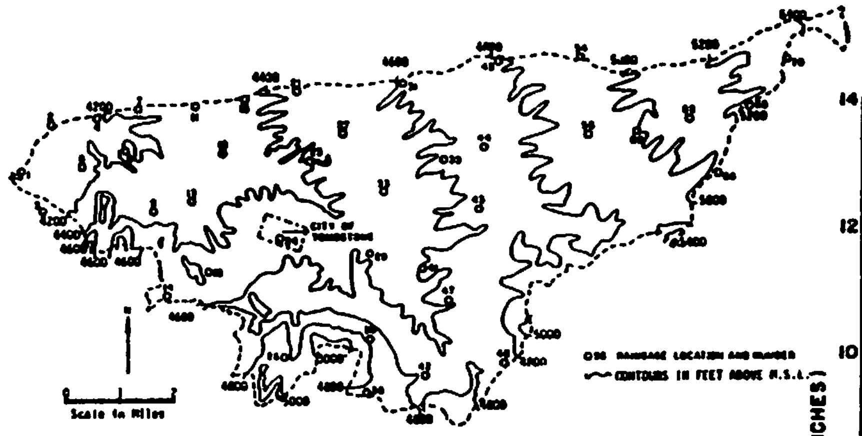


Figure 1. Walnut Gulch relief map and raingage network.

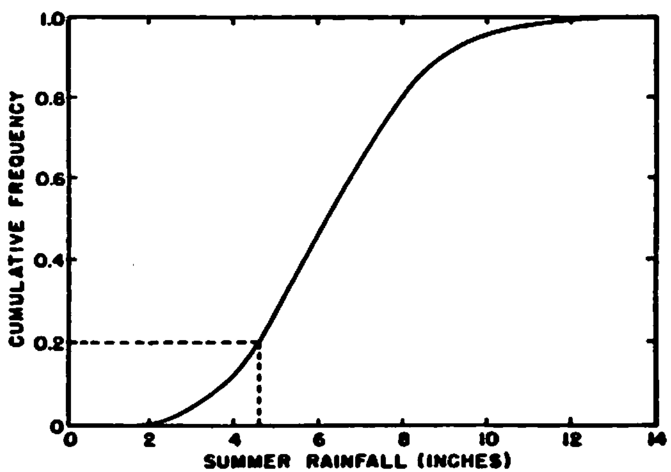


Figure 2. Distribution of summer rainfall on Walnut Gulch.

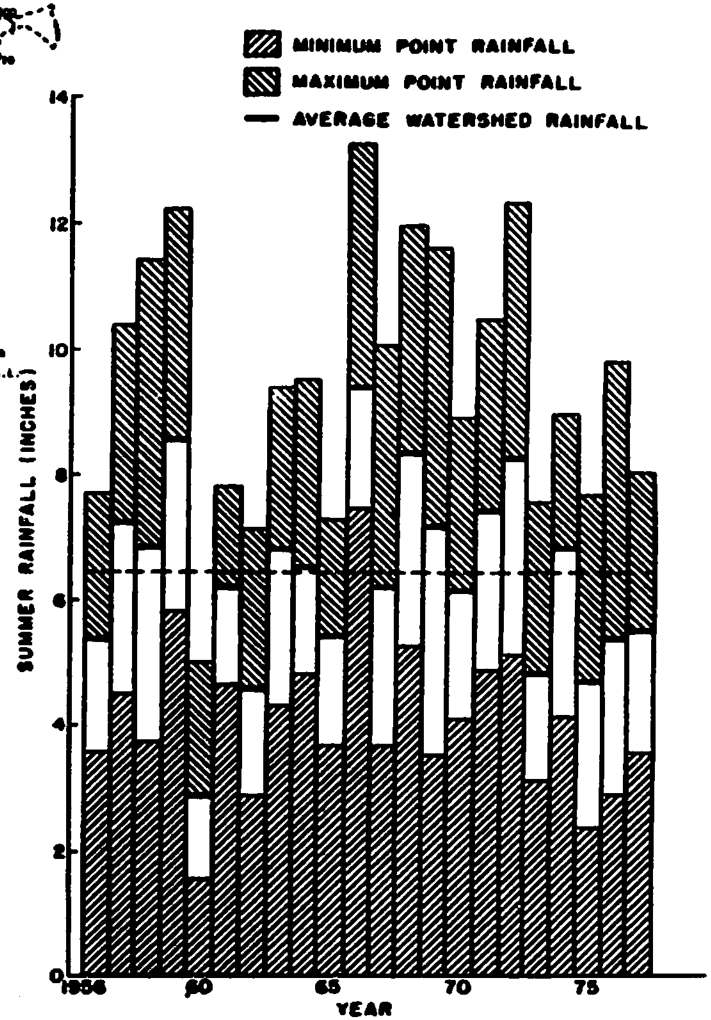
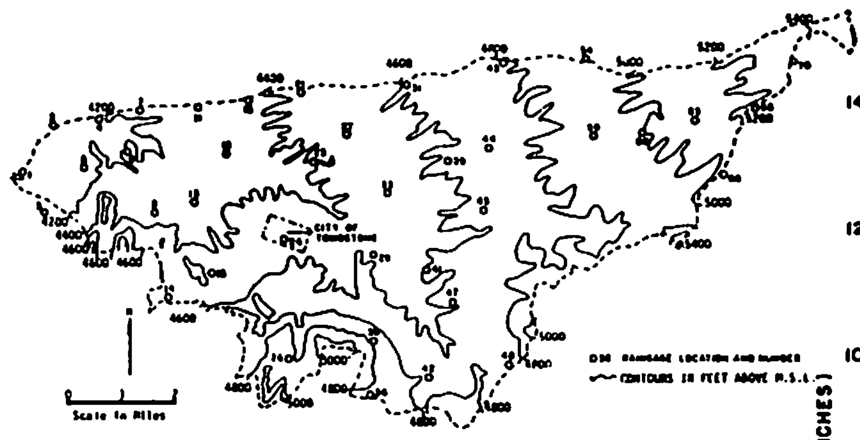


Figure 3. Walnut Gulch summer rainfall.



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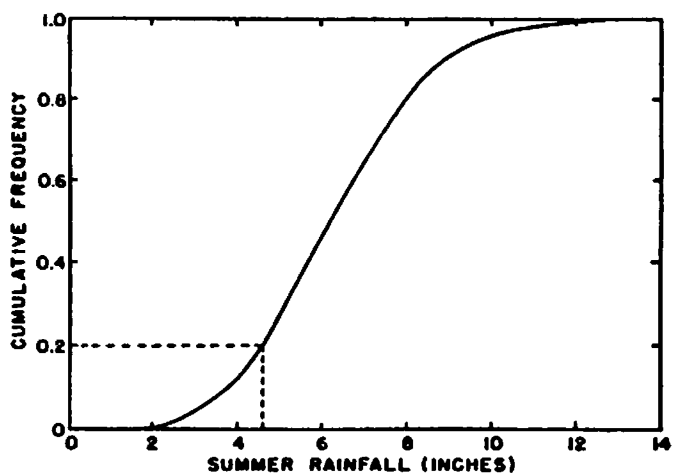

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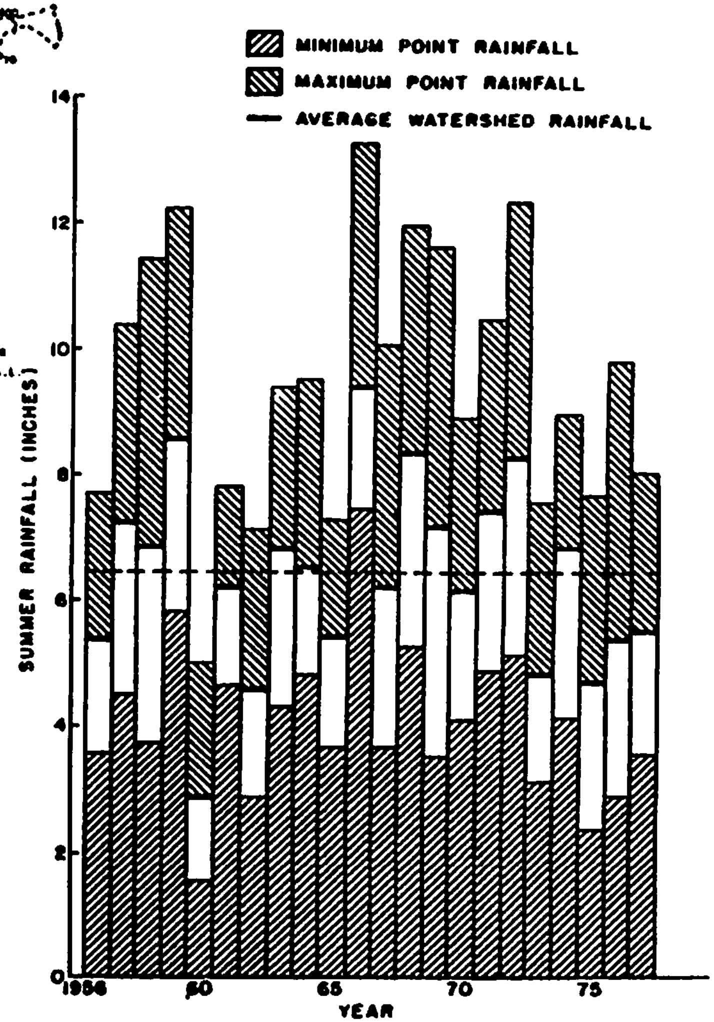

Figure 3. Walnut Gulch summer rainfall.

continuous operation from 1956 through 1977. For this study, summer months were considered as June, July, and August, since this is the maximum period of growth for many range species. Major vegetation of the watershed includes: creosote bush (*Larrea tridentia*), white-thorn (*Acacia constricta*), tarbush (*Flourensia cernua*), snakeweed (*Gutierrezia Sarothrae*), burroweed (*Aplopappus tenuisectus*), black grama (*Bouteloua eriopoda*), blue grama (*B. gracilis*), sideoats grama (*B. curtipendula*), and bush muhly (*Muhlenbergia porteri*).

The non-parametric technique developed by Robinson and Fesperman essentially uses the quantile values of precipitation amount at each station to identify times of low precipitation. In this way, differences in annual and seasonal means within the region, due to such factors as elevation and aspect, are eliminated. We also adapted the method to the case in which we assume that the distribution function of summer rainfall is the same for all gages on Walnut Gulch.

RESULTS

In the first case, assuming long-term differences because of gage location and elevation, the annual summer rainfall amounts were ranked in order for each gage, the largest to the smallest, and the years with rainfall below the 20th percentile were considered deficit. The four years which were considered deficit at each gage are marked with an "x" (Table 1). In the second case, where summer rainfall was considered completely random, all summer point (raingage) amounts were ranked together, and those below the 20th percentile were considered deficit. There were as many as eight deficit years at some gages and a minimum of one year at two gages (Table 2, Fig. 2).

Yearly average, maximum and minimum summer rainfall amounts for the 38-gage network are shown in Fig. 3. Average summer rainfall for the 22-yr record was 6.44 inches and ranged from 2.92 inches (1960) to 9.46 inches (1966), with point values ranging from 1.57 inches (1960) to 13.24 inches (1966). Average point summer rainfall varied from 5.63 inches to 7.17 inches (Fig.4). In the "driest" summer (1960), the watershed average was 2.92 inches, with a point range of 1.57 to 5.02 inches (Fig. 5), and well below average rainfall was recorded over the entire watershed. In contrast, in 1966, the "wettest" summer, the average rainfall was 9.46 inches, with a range of 7.47 to 13.24 inches, and the entire watershed had above average rainfall (Fig. 6). Average annual precipitation for the 22-yr record was 11.46 inches, and summer rainfall amounted to 56% of annual precipitation. Fall (Sep.-Nov.), winter (Dec.-Feb.), and spring (Mar.-May) precipitation were 23%, 14%, and 7%, respectively, of annual precipitation.

Based on the assumption that differences in average summer rainfall (Fig. 4) represented real long-term differences associated with gage site and elevation, there were deficits on significant portions of the watershed in six of the 22 years of record (Fig. 7-11). However, there was below average rainfall over the entire watershed only in 1960. In 1962, 1970, 1973, 1975, and 1976, summer deficits occurred on significant portions of the watershed, but other parts of the watershed received above average rainfall (Fig. 7-11). Deficit summer rainfall

TABLE 1. Deficit Summer Rainfall On Walnut Gulch, 1956-1977.

Year	Raingage Number																																				
	02	03	04	05	07	08	09	11	13	14	15	16	18	21	23	24	26	27	29	30	31	33	36	39	41	42	43	44	45	47	48	54	56	60	65	66	68	70
1956		X	X		X									X		X				X						X		X			X				X			X
1957																																						
1958																																X		X		X	X	X
1959																																						
1960	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1961																																						
1962	X	X		X				X			X			X	X				X					X	X		X	X		X	X	X	X	X	X	X	X	X
1963																																						
1964																	X						X															
1965						X	X											X			X			X						X			X					
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1967	X		X		X						X											X					X						X					
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1970						X						X	X	X	X	X		X																				
1971																																						
1972																																						
1973								X									X		X	X		X	X		X	X			X	X	X			X	X	X	X	X
1974																					X			X														
1975	X	X	X	X	X	X	X	X	X	X	X	X	X				X				X						X	X	X			X	X					
1976									X	X		X	X	X	X			X	X		X	X		X	X				X									
1977				X			X	X		X						X																						

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Year	Raingage Number																																				
	02	03	04	05	07	08	09	11	13	14	15	16	18	21	23	24	26	27	29	30	31	33	36	39	41	42	43	44	45	47	48	54	56	60	65	66	68	70
1956		X	X		X									X		X				X						X		X			X				X			X
1957																																						
1958																																X		X		X	X	X
1959																																						
1960	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1961																																						
1962	X	X		X				X			X			X	X				X					X	X		X	X		X	X	X	X	X	X	X	X	X
1963																																						
1964																	X						X															
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1966																																						
1967	X		X		X						X											X					X						X					
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1970						X						X	X	X	X	X		X																				
1971																																						
1972																																						
1973								X									X		X	X		X	X		X	X			X	X	X			X	X	X	X	X
1974																					X			X														
1975	X	X	X	X	X	X	X	X	X	X	X	X	X				X				X						X	X	X			X	X					
1976									X	X		X	X	X	X			X	X		X	X		X	X				X									
1977				X			X	X		X						X																						

Table 2. Gages Recording Deficit summer rainfall on Walnut Gulch, 1956-1977, based on random distribution of summer rainfall.

Year	Raingage Number																																				
	02	03	04	05	07	08	09	11	13	14	15	16	18	21	23	24	26	27	29	30	31	33	36	39	41	42	43	44	45	47	48	54	56	60	65	66	68	70
1956	0	0	0		0									0												0		0			0				0		0	
1957		0																																				
1958																																		0	0	0	0	
1959																																						
1960	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961																																						
1962	0	0		0							0	0		0										0			0	0	0	0	0	0	0	0	0	0	0	0
1963																					0						0											
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1965	0	0	0	0		0															0			0						0	0							
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1974																					0			0														
1975	0	0	0	0	0	0	0	0	0	0	0	0	0								0						0	0	0			0		0	0			
1976				0					0			0		0	0			0	0		0	0		0	0		0		0									
1977		0		0			0	0																														

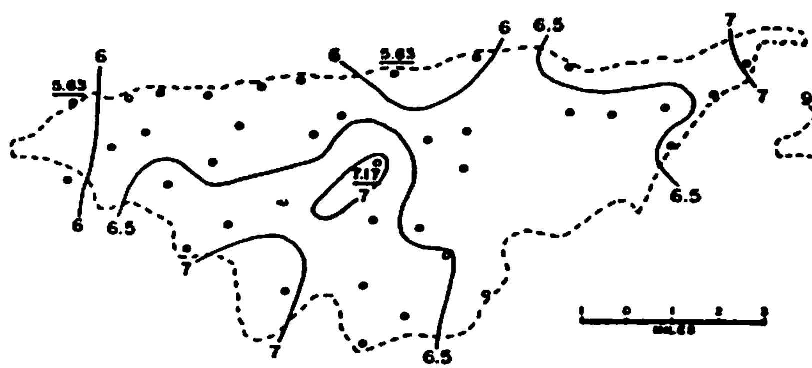


Figure 4. Mean summer rainfall on Walnut Gulch, 1956-1977.

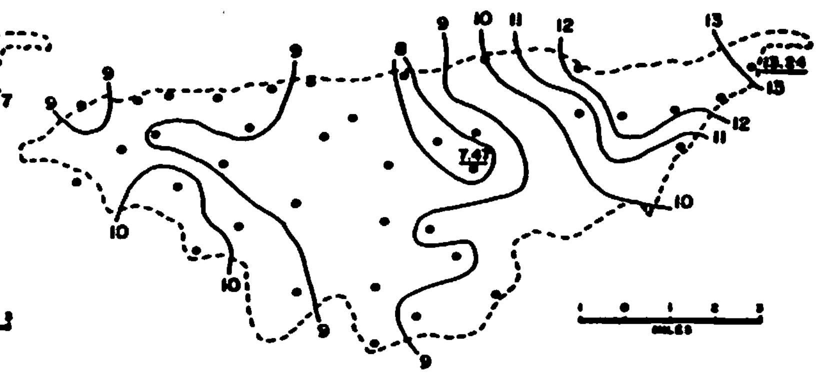


Figure 6. Summer rainfall on Walnut Gulch, 1966.

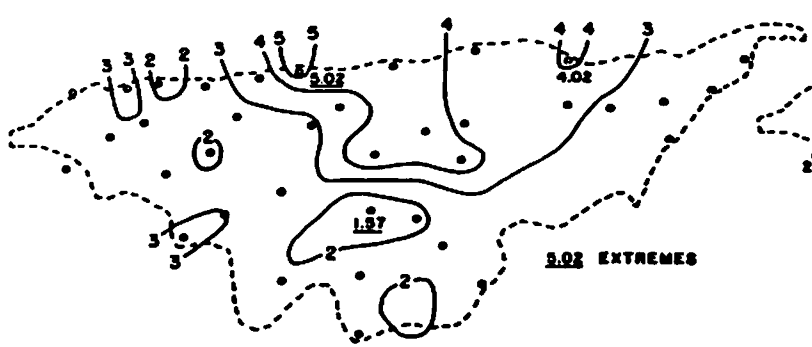


Figure 5. Summer rainfall on Walnut Gulch, 1960.

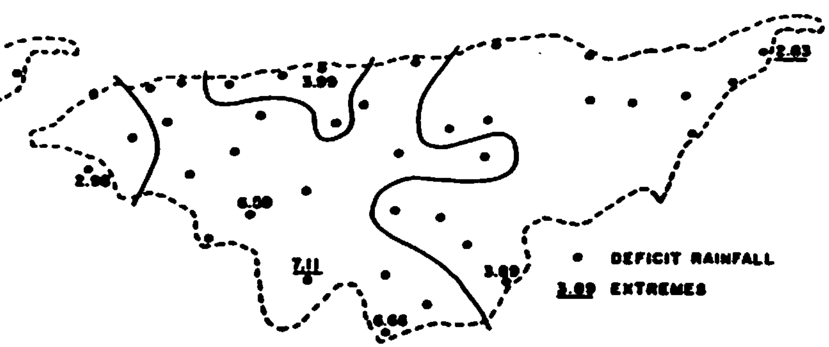


Figure 7. Deficit 1962 summer rainfall on Walnut Gulch, 1962.

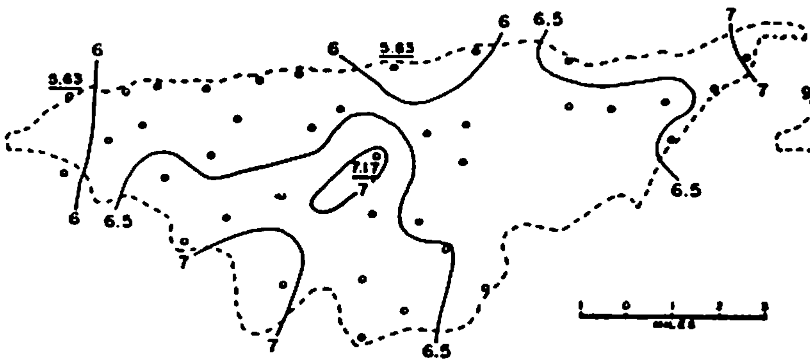


Figure 4. Mean summer rainfall on Walnut Gulch, 1956-1977.

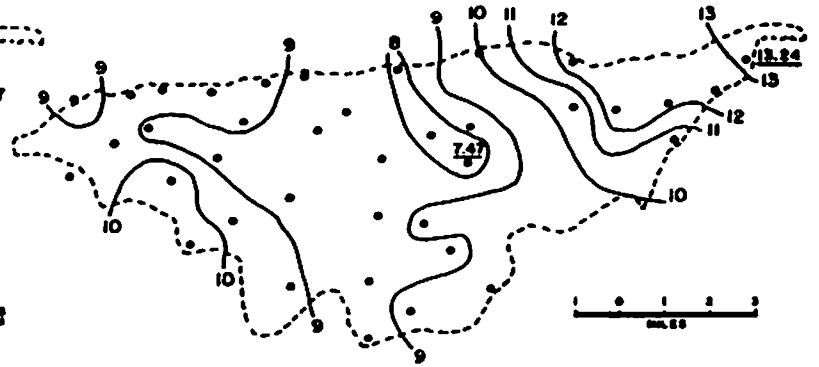
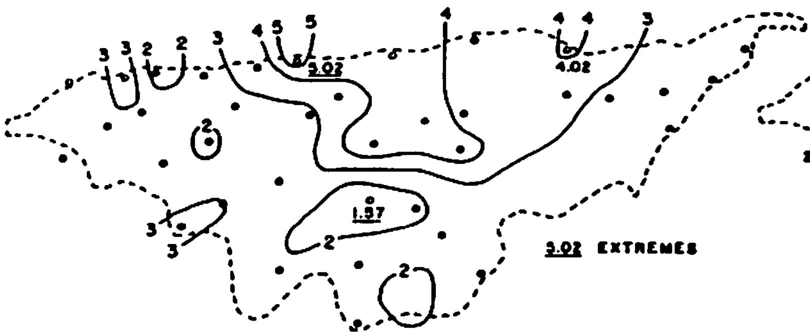


Figure 6. Summer rainfall on Walnut Gulch, 1966.



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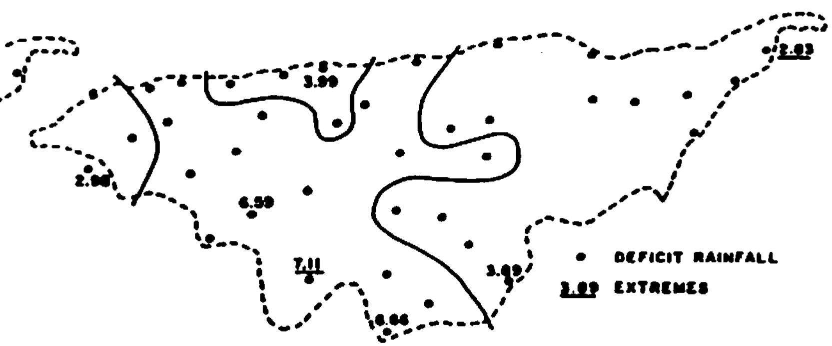

Figure 7. Deficit 1962 summer rainfall on Walnut Gulch, 1962.

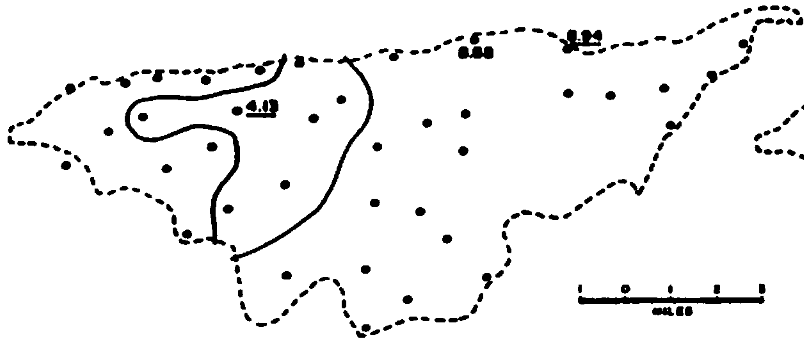

Figure 8. Deficit 1970 summer rainfall on Walnut Gulch.

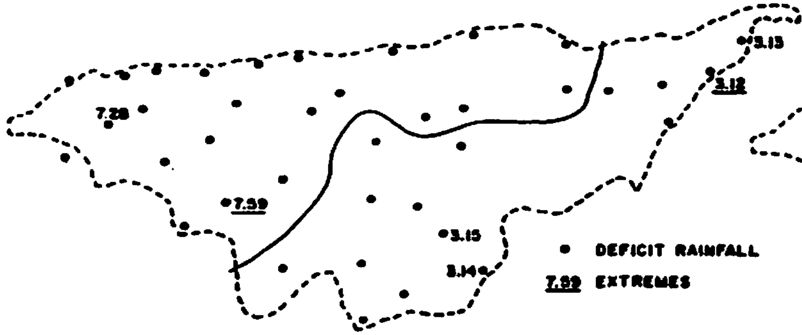

Figure 9. Deficit 1973 summer rainfall on Walnut Gulch.

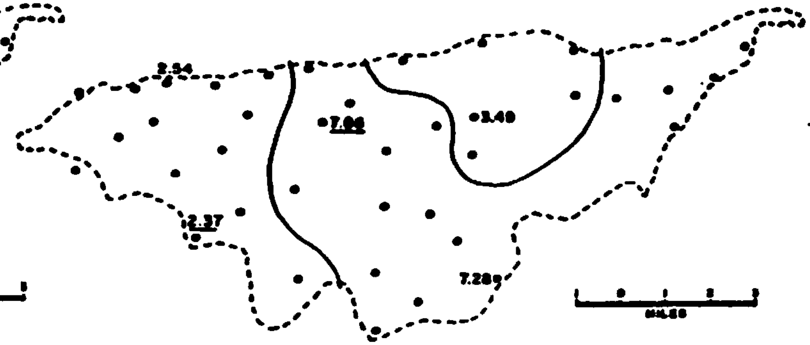

Figure 10. Deficit 1975 summer rainfall on Walnut Gulch.

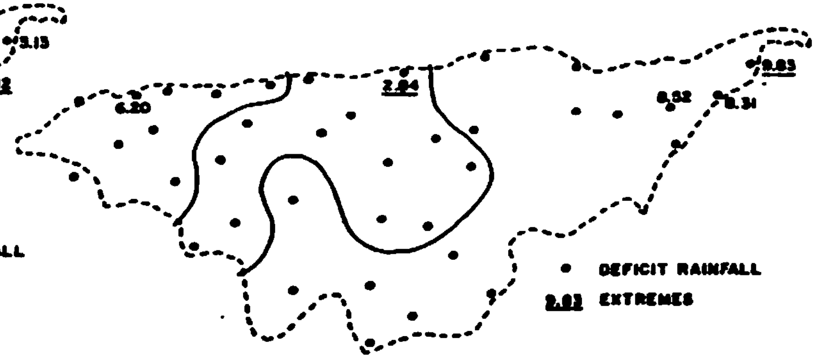

Figure 11. Deficit 1976 summer rainfall on Walnut Gulch.

was recorded at over half of the raingages in 1962, although several raingages recorded above average rainfall (Fig. 7). The minimum and maximum in 1962 were 2.83 and 7.11 inches. A portion of the lower end of the watershed received deficit rainfall in 1970, whereas most of the watershed received average or above average rainfall. Summer deficits were recorded on about half of the watershed in 1973 and 1975 (Fig. 9 and 10). The minimums and maximums were 3.12 and 7.59 inches in 1973, and 2.37 and 7.86 inches in 1975. A deficit was recorded on about 33% of the watershed in 1976, with a minimum and maximum of 2.84 and 9.83 inches (Fig. 11).

In other words, while a portion of the watershed may be extremely dry, other portions may receive well above average rainfall. The greatest recorded difference between maximum and minimum summer rainfall, 7.90 inches, occurred in 1969, when the minimum and maximum were 3.50 and 11.40 inches. In most summers, the minimum point rainfall was less than 50% of the maximum. In 1960, 1969, 1975, and 1976, the minimum was about 30% of the maximum. In only two summers, both relatively wet, was the minimum more than 50% of the maximum. In eight of the 22 years, none of the 38 gages recorded deficit summer rainfall.

We also analyzed the 22 years of data assuming that long-term summer rainfall is randomly distributed on Walnut Gulch. When all summer rainfall data were lumped together, deficit gage/years (below the 20th percentile) were those with less than 4.60 inches of rainfall (Fig.2). Based on this assumption, the lower end of the watershed was considerably drier than most of the watershed, and the south central portion was much wetter than most of the watershed (Fig. 4 and 12).

DISCUSSION

There was no indication, at least for the 22 years of record, of a persistence in deficit summer rainfall from year to year on any portion of the watershed. There were differences in mean summer rainfall between raingages (Fig. 4), which could be meaningful in terms of range conditions. Furthermore, a suggestion of possible nonrandom distribution of deficit summer rainfall (Fig. 12) needs to be explained. Further analyses are in order when more years of data are available.

SUMMARY

A simple non-parametric technique (Robinson and Fesperman, 1986) was used to investigate the possible persistence of summer rainfall deficits on the Walnut Gulch experimental watershed in southeastern Arizona. By ranking summer rainfall at each raingage from the largest to the smallest amount and looking at the lowest 20th percentile, we reaffirmed the extreme variability of summer rainfall on a 58-sq-mi rangeland watershed, but found no evidence of persistence in deficit rainfall on any particular portion of the watershed. However, the data did suggest a possible non-random pattern of summer rainfall that could not be readily explained, and suggested that when more data are available further evaluation would be appropriate.

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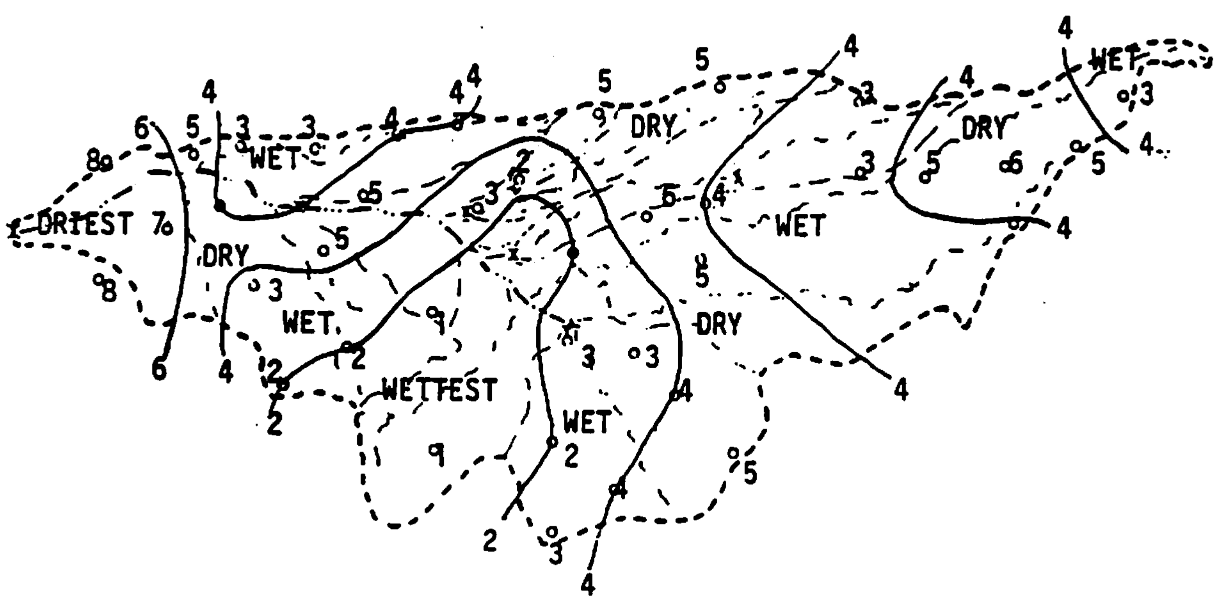

Figure 12. Distribution of deficit summer rainfall (<4.60") on Walnut Gulch.