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Precipitation Variability in the Columbia Basin of Washington

Abstract

This paper describes time and space variability of precipitation in the semiarid climate of the Columbia Basin in Washington State. Annual variation, as indicated by the coefficient of variation, averages 24.47 percent for the 19 stations used in the analysis. Variation is greater during spring and summer months than during fall and winter. Average annual precipitation increases about 2.47 cm for each 100 m increase in elevation. Simple correlation of annual or seasonal precipitation decreases rapidly as distance between stations increases.

Introduction

Climate of the Columbia Basin in Washington State is classified as semiarid because potential evaporation during each year exceeds annual precipitation amounts (Trewartha, 1943). Precipitation usually occurs in the form of general cyclonic storms during the winter months and thunderstorms during the warm months. Because thunderstorm cells usually cover a limited land surface area, variation in amounts of rainfall between measuring sites is usually very large. In fact, extreme variability of precipitation from year to year and from point to point within a given year is one characteristic of semiarid zones (Trewartha, 1943). The objective of this research was to use historical precipitation records to describe the variation in annual precipitation amounts from year to year at individual sites, and from site to site within individual years.

Study Area

The Columbia Basin is located in the east-central part of Washington State. Prevailing winds are from west to east; thus, a major rain shadow is created by the Cascade Range, which is oriented north-south, roughly parallel to the Pacific Ocean and located just west of the Columbia Basin. Figure 1 shows the location of the study area and the precipitation stations which were used in this analysis. The stations vary in elevation from 169 m at Trinidad to 798 m at Waterville. Conclusions drawn here are directly applicable only to the area represented by the stations identified in Figure 1. However, comparison of these results with results from other semiarid areas may indicate more general application.

Precipitation records in the Columbia Basin began in the latter part of the nineteenth century. In 1900, there were 27 reporting stations in eastern Washington. During this



Figure 1. Relative location of the climatic station used in the analysis.

century, several new stations were started, operated a few years, and then discontinued. Also, some original stations were closed when volunteer operators moved away. Even today, the rain gauge density is extremely sparse with an average of only one gauge per 971 sq km, or an average distance of 30.4 km between gauges. In some areas, rain gauges are more than 50 km apart.

Previous Work

The magnitude of the correlation of precipitation or temperature measured at two stations depends on the distance between the stations. As distance between the stations increases, correlations usually decrease. Godshall (1977) computed the correlation of air temperature between stations as much as 1610 km apart. His highest correlation was about 0.8 between stations which were no more than 80 km apart. As distance increased between the reference and test stations, correlations decreased logarithmically; at 1280 km, the values had declined to about 0.2. The same general relationships were presented by Longley (1974) for precipitation data in the prairie provinces of Canada. Longley was able to plot general storm tracks during the summer months based on his correlation analysis.

Methods

Data published by the U.S. Weather Bureau were used to determine precipitation

variability. The data are summarized by season (August-February and March-July) and water year (August-July). The water year is started on 1 August because August usually is the driest month of the year. Also, it represents the approximate date when the native vegetation, big sagebrush (*Artemisia tridentata* Nutt.), stops growing.

Analyses of each season were made in which the correlations of annual precipitation between a selected base station and each of the other stations listed in Figure 1 were computed. Next, the distance between the base station and each of the other stations was measured on a map. A graph was plotted in which the correlation coefficient between stations was the dependent variable and distance between the same stations was the independent variable.

Results and Discussion

Tables 1, 2, and 3 contain statistics on annual, spring-summer, and fall-winter precipitation, respectively (including averages, standard deviations, coefficients of variation, as well as the record length and elevation of each station used in this study). Periods of record vary from 27 to 45 years, and annual averages vary from 19.3 cm at the Ephrata Airport to 36.7 cm at Winthrop. Although the elevation range is limited, there is a slight increase in average annual precipitation with elevation (Fig. 2).

The regression of average annual precipitation on elevation was determined as follows:

$$\text{Precipitation (cm)} = 13.25 + 0.247 (\text{elevation, m})$$

This function, which has a coefficient of determination (r^2) of 0.47, indicates that average annual precipitation increases 2.47 cm for each 100 m increase in elevation. The regression is significant ($P \leq 0.01$).

Plottings were made of correlation coefficient (r) and distance between pairs of climatic stations. In general, the relationship presented in Figure 3, in which Wenatchee

TABLE 1. Average annual precipitation (1 August-31 July) and its variation between years.

Station	Elevation (m)	Precipitation			Years of record
		average (cm)	standard deviation (cm)	coefficient of variation (percent)	
Davenport	750	40.9	8.8	22	43
Ellensburg	463	22.8	5.6	24	40
Ephrata	389	20.3	5.5	27	43
Ephrata Airport	384	19.3	4.7	24	27
Grand Coulee	518	26.6	6.6	25	41
Hartline	582	27.0	6.5	24	27
Lind	497	23.3	4.9	21	28
Mansfield	690	26.9	5.0	21	27
Moses Lake	368	19.5	4.6	23	27
Moxee City	472	19.8	5.8	29	28
Odessa	469	26.0	7.0	27	45
Othello	363	20.2	6.1	30	27
Quincy	388	20.5	5.5	28	27
Ritzville	558	28.4	5.9	20	27
Trinidad	169	21.0	5.6	27	29
Waterville	799	28.9	6.8	24	45
Wenatchee	193	22.8	5.5	24	45
Wilson Creek	389	22.4	4.9	22	28
Winthrop	535	36.7	8.4	23	44

TABLE 2. Average precipitation between 1 August and 1 March and its variation between years.

Station	Precipitation		coefficient of variation (percent)
	average (cm)	standard deviation (cm)	
Davenport	26.6	6.1	23
Ellensburg	15.5	4.0	26
Eprata Airport	12.7	3.6	28
Ephrata	13.1	3.8	29
Grand Coulee	16.4	4.2	26
Hartline	17.8	5.1	29
Lind	15.5	4.5	29
Mansfield	17.9	4.9	28
Moses Lake	12.8	3.4	27
Moxee City	12.6	4.0	32
Odessa	16.5	4.2	26
Othello	13.6	5.5	40
Quincy	13.4	4.0	30
Ritzville	19.1	5.2	27
Trinidad	13.4	3.8	29
Waterville	19.1	5.7	30
Wenatchee	16.0	4.4	28
Wilson Creek	14.9	4.0	27
Winthrop	26.5	7.5	28

TABLE 3. Average precipitation between 1 March and 1 August and its variation between years.

Station	Precipitation		coefficient of variation (percent)
	average (cm)	standard deviation (cm)	
Davenport	14.3	5.9	41
Ellensburg	7.3	3.8	52
Ephrata Airport	6.6	3.1	48
Ephrata	7.2	3.7	51
Grand Coulee	10.2	5.1	50
Hartline	9.2	3.6	40
Lind	7.8	2.0	26
Mansfield	9.0	3.7	41
Moses Lake	6.7	2.1	31
Moxee City	7.2	3.5	48
Odessa	9.5	5.0	52
Othello	6.6	2.7	41
Quincy	7.1	3.5	49
Ritzville	9.3	3.0	32
Trinidad	7.6	4.5	59
Waterville	9.8	5.3	54
Wenatchee	6.8	4.3	43
Wilson Creek	7.5	3.0	40
Winthrop	10.2	4.7	46

and Ephrata are used in turn as the base stations, is typical. Although the graph indicates the expected inverse relationship between correlation and distance, the logarithmic relationship presented by Longley (1974) is not evident. One reason for this lack may be the limited distance between stations in the Columbia Basin. Longley's maximum distance between stations was 1200 km, compared to the maximum of only 200 km in this study.

Another way to present correlation data is to select a base station near the center

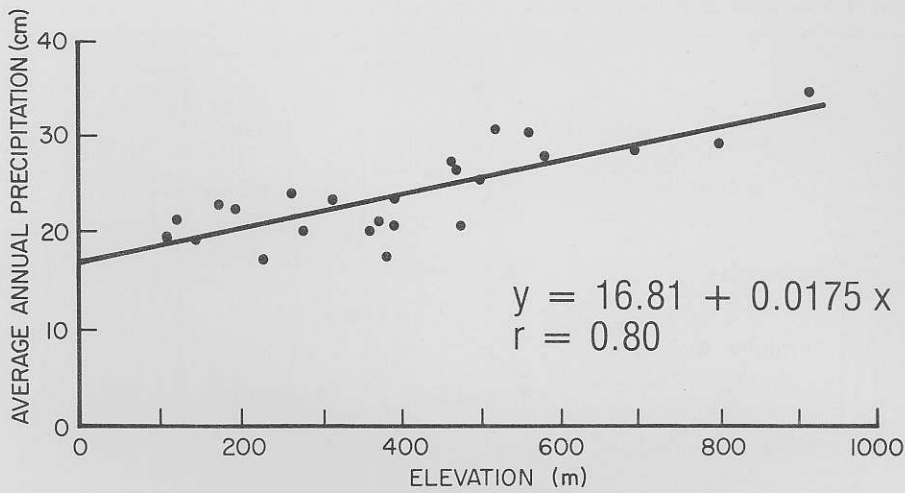


Figure 2. Relationship between elevation and average annual precipitation.

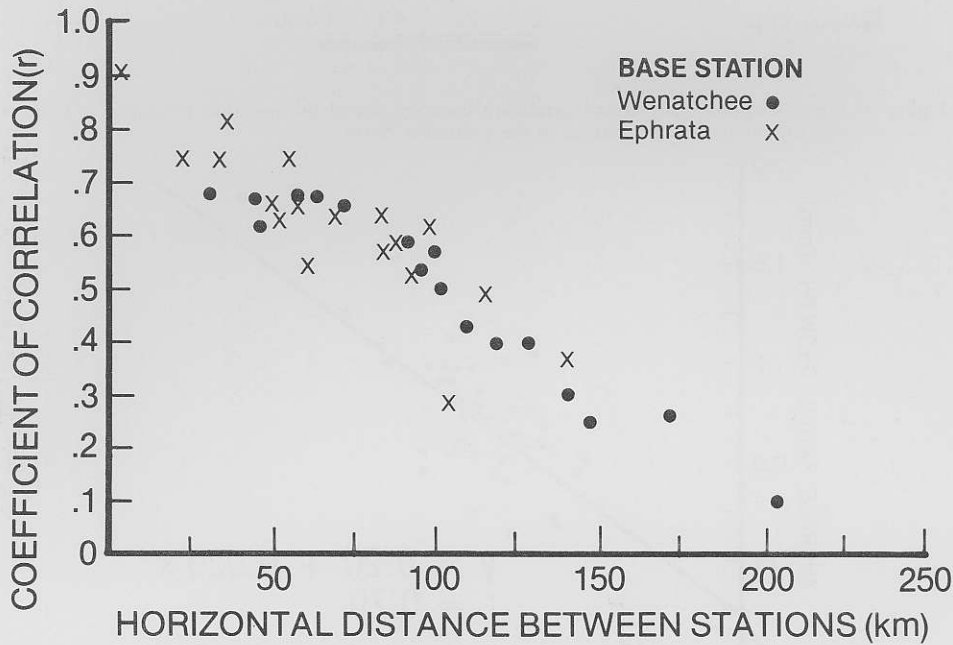


Figure 3. Relationship between correlation of annual precipitation (August-July) and distance between stations. Wenatchee and Ephrata are used in turn as the base stations.

of the study area and draw lines of approximately equal correlation based on data from surrounding stations. Figure 4 uses Ephrata as the base station. This figure illustrates the reliability of estimating annual precipitation at an ungauged site from records collected some distance away. Correlation at 32 km is about 0.7; at 64 km it drops to about 0.6. Figure 4 clearly illustrates the uncertainty in using records from an estab-

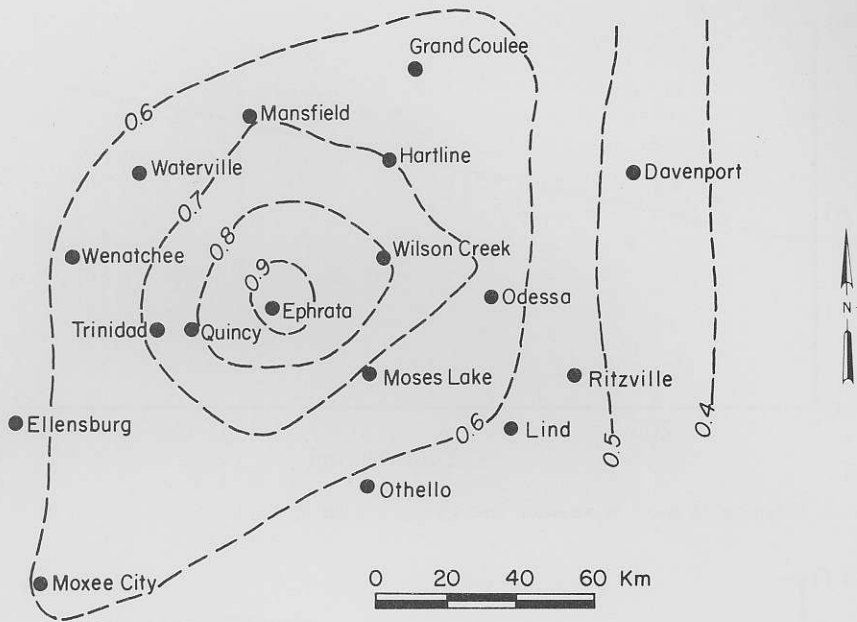


Figure 4. Lines of approximate equal correlation between annual precipitation measured at Ephrata and the other climatic stations in the Columbia Basin.

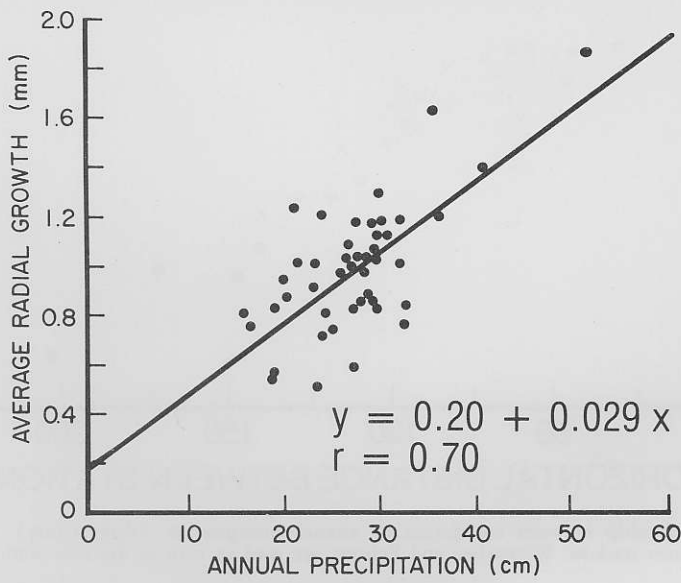


Figure 5. Relationship between average annual radial growth of sagebrush growing at Steamboat Rocks and measured annual precipitation at Mansfield.

lished climatic station to estimate annual precipitation at ungauged sites more than a few kilometers away.

We (Fowler and Helvey, 1974) reasoned that native plants growing at remote sites would provide an alternative way to estimate annual precipitation at those sites during past years. Although our preliminary results (Fig. 5) are encouraging, more testing is needed before a model can be developed to predict rainfall amounts from annual radial increments of sagebrush growth. Variables needed to be evaluated, in addition to precipitation, include the following: elevation, soil fertility, and land use history (i.e., fire, grazing, and so forth). Until such models are developed, or the rain-gauge networks expanded, estimates of annual or seasonal precipitation at points several kilometers away from established gauges will not be precise.

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