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Annual Precipitation on the Island of Hawaii between 1890 and 1977[1]

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ABSTRACT: Long-term annual precipitation records from 31 stations on the southeast and windward sides of the island of Hawaii were analyzed by a simple linear regression technique for possible significant trends during the approximate period 1900–1977. Records from stations along the windward side of the island showed a general downward trend and along the southeast side of the island a general upward trend. An explanation for these trends has not been found; however, a shift in tradewind direction has been suggested as a possible cause. Wind direction records are not complete enough to establish a relationship between the two trends. The decrease in annual precipitation around the Waimea area represents a significant effect on water resources of the area.

PRECIPITATION RECORDS from the southeast and windward sides of the island of Hawaii were examined to determine if any unusual trends exist. Originally this study was initiated as a search for relationships between precipitation patterns and ohia decline on the island. Petteys, Burgan, and Nelson (1975) reported that aerial photographs showed that a large portion of the ohia forest on the windward side of the island was in a state of decline in 1954. No relationships were found, but records on the windward side showed consistent downward trends in annual precipitation. Records from stations on the southeast side showed consistent upward trends.

In the drier areas, such as around Kamuela, the downward trend may affect the amount of precipitation available for plant growth and water supplies. The reason for this trend is not clear, but it may be related to a change in the tradewind pattern (Wentworth 1949).

This study analyzes, statistically and through use of a drought index procedure, precipitation records for the southeast and windward sides of the island of Hawaii, for the approximate period 1900 to 1977. It also examines records of tradewind direction for the same period, for possible correlation between tradewinds and precipitation.

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METHODS

Records of all precipitation stations on the southeast and windward sides of the island of Hawaii were examined, and 31 stations with records longer than 50 years were selected for further analysis (Figure 1). Some records went back as far as 1890, but most were for the period 1900 to 1977. Annual precipitation records from each station were analyzed by simple linear regression to detect any significant trend with time. Annual precipitation data were also analyzed by using a drought index procedure similar to that used by Foley (1957).

RESULTS

Mean annual precipitation for the 31 stations examined ranged from 65 to 620 cm. All of the stations within the windward area boundaries (hydrographic areas 81 and 82 in Figure 1) had downward regression lines. Six of these sloped downward significantly (Table 1). Some stations, such as Kamuela (Figure 2), had as much as a 50-cm reduction in annual precipitation during the period examined. This represents a 40 percent reduc-

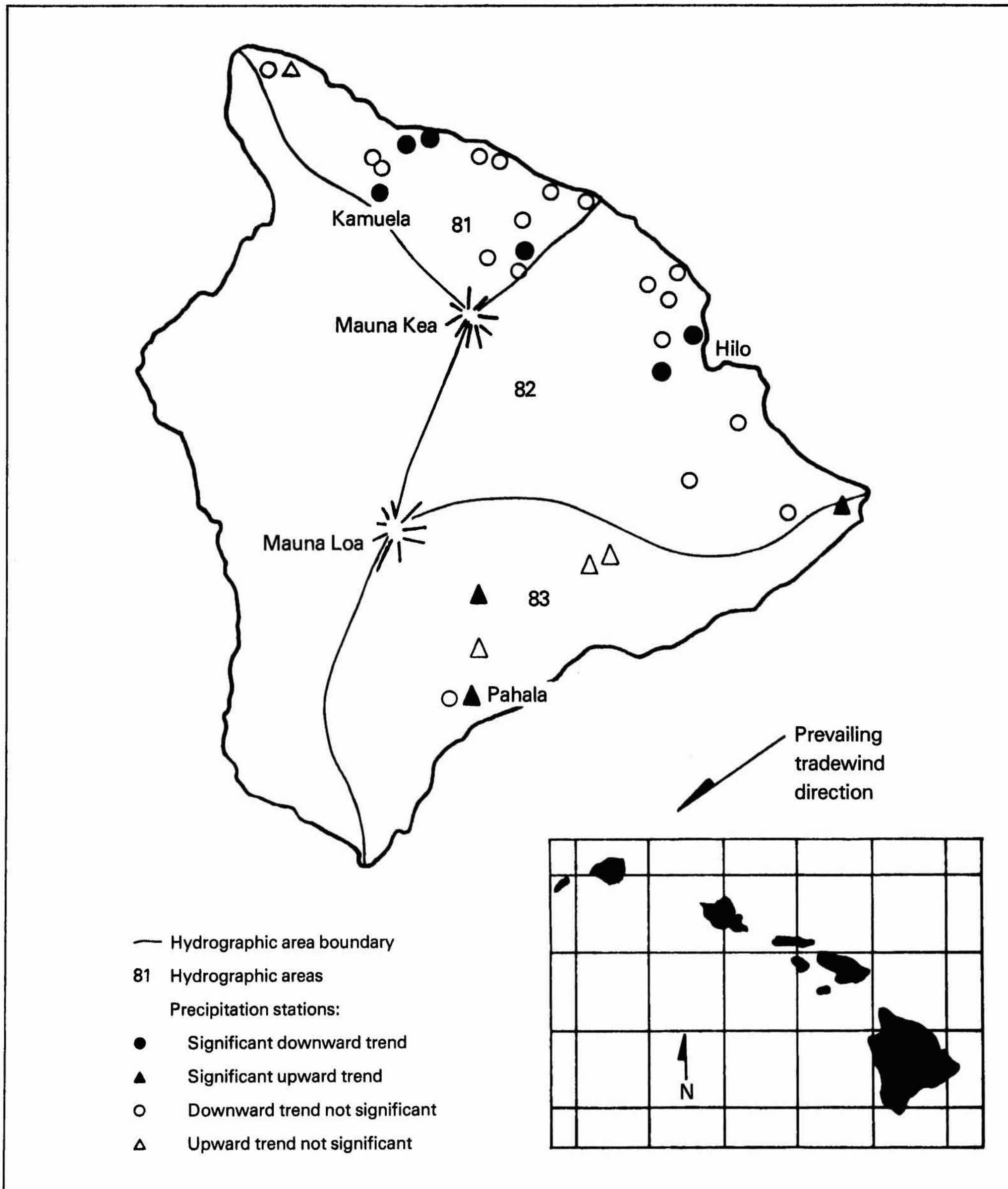

FIGURE 1. Precipitation stations analyzed in this study.

tion in precipitation for that station. All but one station on the southeast side of the island (hydrographic area 83 in Figure 1) had regression lines with an upward slope, illustrated by Pahala station (Figure 3). For two stations this upward slope was significant.

Little information was obtained from the analysis that used a drought index procedure except for the following: (1) at those stations with records back to 1890, precipitation was 20 to 25 percent below normal for the 11 years from 1890 to 1901; (2) at all stations, annual

TABLE 1

REGRESSION ANALYSIS OF ANNUAL PRECIPITATION BY YEAR AT 31 PRECIPITATION STATIONS, ISLAND OF HAWAII, 1890–1977

STATION NUMBER AND NAME	ANNUAL PRECIPITATION MEAN (cm)	YEARS OF RECORD	REGRESSION ANALYSIS, ANNUAL PRECIPITATION VS. YEAR
	HYDROGRAPHIC AREA 81		
192.2 Kamuela	99.3	78	−0.71*
118.0 Umikoa	202.2	75	− .66
117.0 Halepiula	110.2	61	− .79*
113.0 Puu Mali	63.5	42	− .23
168.0 Hawi	130.8	78	− .36
175.1 Kohala Mission	151.9	88	+ .20
199.0 Kukuihaele	207.3	68	−1.47*
206.0 Kukuihaele Mill	160.0	87	− .69*
214.0 Haina	170.4	88	− .20
223.0 Ookala	288.0	79	− .41
120.0 Puu Kihe	106.4	60	− .18
193.0 Kawainui Lower	428.5	68	− .05
196.0 Koiawe Lower	270.8	68	− .30
217.0 Paauhau	167.1	88	− .13
222.0 Kukaiau	266.7	83	− .01
	HYDROGRAPHIC AREA 82		
89.0 Piihonua	620.3	54	−1.42*
144.1 Papaikou	399.5	80	−1.73*
138.0 Honomu Mauka	546.1	66	−1.52
135.0 Hakalau Mauka	531.4	55	−2.21
91.0 Mt. View	418.8	78	− .64
140.1 Papaikou Mauka	351.4	53	− .23
65.0 Pahoa	375.2	62	− .01
92.0 Keaau	363.5	78	− .23
142.0 Hakalau	342.9	86	− .23
	HYDROGRAPHIC AREA 83		
93.0 Kapoho	252.5	68	+ .76*
54.0 Park Headquarters	254.2	64	+ .48
18.0 Moaula	118.9	57	− .30
21.0 Pahala	118.4	86	+ .38*
37.0 Pakao	165.4	47	+ .97
52.0 Halemaumau	128.0	45	+ .20
36.0 Kapapalia Ranch	159.0	77	+ .08

* Significant at the 5% level.

precipitation was 10 to 30 percent below normal during the last 8 to 10 years or most of the 1970s; and (3) precipitation was above normal for prolonged periods of time in the late 1930s.

DISCUSSION

Others have examined precipitation trends in Hawaii with varying results (Cox 1924, Meisner 1976, Woodcock 1980). Cox's work was done when the data base was too short to show any trends. Meisner took representative stations throughout the Hawaiian Islands and lumped them by using a weighting procedure to establish an annual index value for the islands. His data indicated a slight upward trend in winter rainfall and a 30-year cyclic pattern. Meisner did not compare the long-term data among various portions of the island of Hawaii. Woodcock used Meisner's data to show the downward trend in precipitation from 1965 to 1980.

At about the turn of the century it was

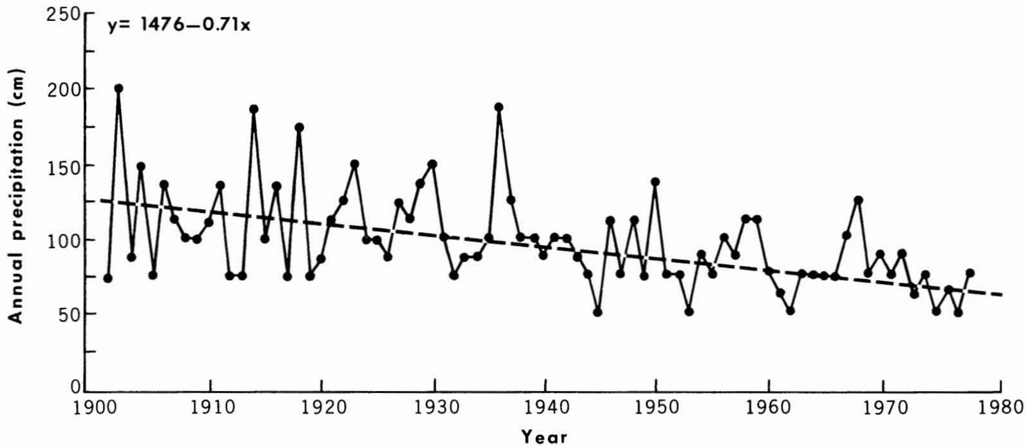

FIGURE 2. Annual precipitation at the Kamuela gauge no. 192.2. Dashed line represents the simple linear regression, where y = annual precipitation and x = year.

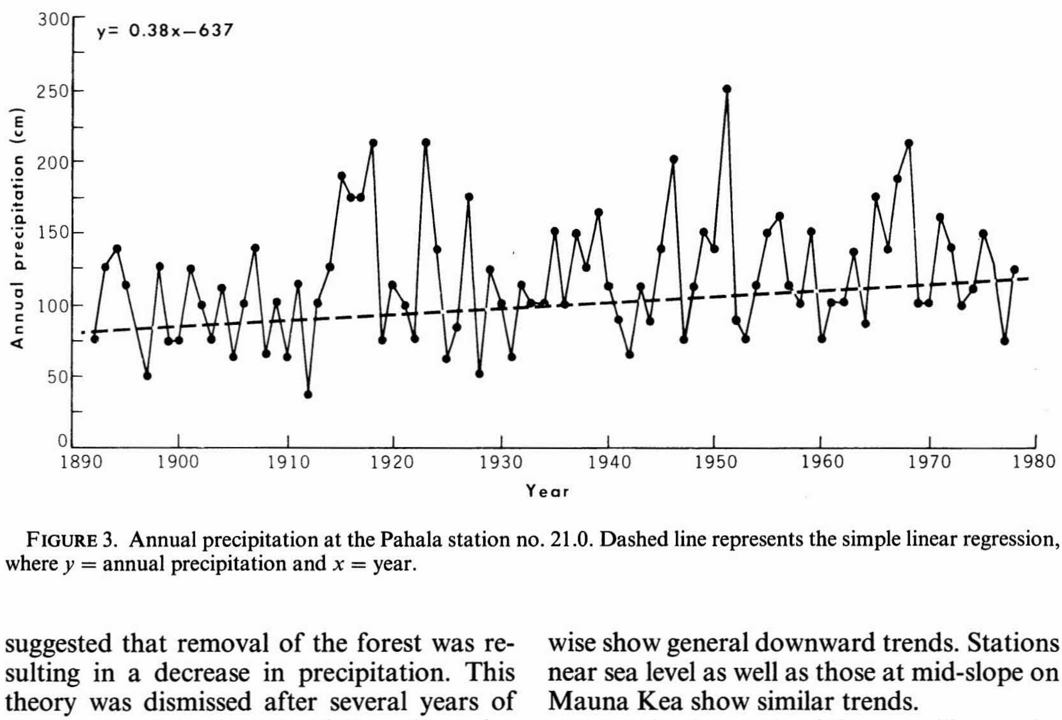

FIGURE 3. Annual precipitation at the Pahala station no. 21.0. Dashed line represents the simple linear regression, where y = annual precipitation and x = year.

suggested that removal of the forest was resulting in a decrease in precipitation. This theory was dismissed after several years of above-normal precipitation followed a major fire that destroyed 12,600 hectares of forest in the Hamakua District (Hawaiian Sugar Planters' Association 1912). However, over the years stations in that area have shown a general downward precipitation trend. But nearly all stations on the windward coast associated with several different land uses likewise show general downward trends. Stations near sea level as well as those at mid-slope on Mauna Kea show similar trends.

I examined records of the prevailing tradewind direction for a possible clue to the long-term trend in precipitation. But Hawaii has no wind recording station that covers the period 1900 to 1977. Records from the weather service station at Honolulu come the closest, but its location was changed in the middle of the period. Wentworth (1949) examined the records of the Honolulu station and, by projecting the trend that he observed, suggested a cyclic pattern with a 45-year period. This suggestion does not appear to coincide with the precipitation pattern I observed. Although the Honolulu station was moved after Wentworth's work, I extended his data up to 1976 and found that the wind direction appears to complete the cycle he suggested in about 60 years. But because of the change in station location and because there was only one cycle to examine, a relationship between wind direction and precipitation could not be confirmed. If the precipitation pattern were to follow closely shifts in the tradewind pattern, the precipitation pattern should have reversed around 1940, which was not apparent.

Regardless of what may be causing the observed trend, the impact on water resources in such areas as the drier plains around Kamuela is important. Precipitation patterns should be further studied in order to assess the potential impact on water supply levels that can be expected if mean annual precipitation continues at present levels, returns to the earlier higher levels, or continues to decrease.

The seasonal distribution of precipitation should also be studied. Such a study would show whether the current lower level of precipitation is more evenly distributed through the year than earlier higher levels. Better seasonal distribution might mean that the downward trend in precipitation does not threaten the amount of water available for plants and water supplies.

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