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Rain Characteristics in Higashiyama Watershed Area

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I. Introduction

In comparing runoff to rainfall on mountainous areas, the accuracy of rainfall data is usually inferior to that of runoff. This is because a rain gauge measures rainfall at a certain spot only, making it difficult to determine areal rainfall.

The amount of rainfall changes according to topographical and meteorological conditions. It is said that it is related closely with elevation.

In this study the accuracy of rainfall data, measured at a representative rain station, is examined using data from the high density network composed of thirteen observation stations in Higashiyama Watershed, Tokyo University Forest in Aichi.

This data was observed by two technicians, Mr. Kazuo Hayashi (obs. 1930–1938) and Tome Nakagawa (obs. 1930–1947). This work must have required great effort, considering the number of gauging stations and the time taken. The experiment was suspended soon after the World War II due to the theft of the rain gauges.

II. Data for Analysis

Higasiyama watershed was established in 1923 as an experimental field for forest hydrology in the Tokyo University Forest located at Seto City, Aichi Prefecture, in the central Japan. It has 106.70 hectares. The river system belongs to the Syohnaigawa and Mizunogawa, and climatology to a warm temperate zone.

Altitude from sea level is 347–617 m. The soil of the area is composed of deeply weathered granite. The general situation of Higasiyama watershed is shown in Table one.

Table 1. Several Elements of Higashiyama Watershed

area (ha)	106.70
altitude (m)	347–617
drainage density (l/km)	4.47
mean gradient (°)	25.0
annual precipitation (mm)	1825
annual runoff (mm)	1000
runcff ratio (%)	54.0
air temperature (°)	13
humidity (%)	80
evaporation (mm/day)	1.8
bare land area (%)	7.1 (1965)
	4.6 (1976)
	2.4 (1989)
forest stand volume (m^3/ha)	87.0 (1964)
	136.1 (1981)
	145.3 (1990)

Vegetation is naturally regenerated forest including Japanese red pines. Pine trees are especially eugenic on the ridge. The bare land is said to have occupied more than ten per cent of the area along the ridge at the time that the observation started.

The experiments were carried out from 1932 to 1947 with thirteen rain gauging stations. The rain gauging network was composed of seven syphon type self recording rain gauges and six storage type ones. Syphon type rain gauges are structually similar to those of storage type, but have a float in the storage tank, so these two types of gauge can be regarded to be mechanically the same and must have been very accurate. But no record was made of which type of gauge was used in which location.

The volume of rainfall were measured

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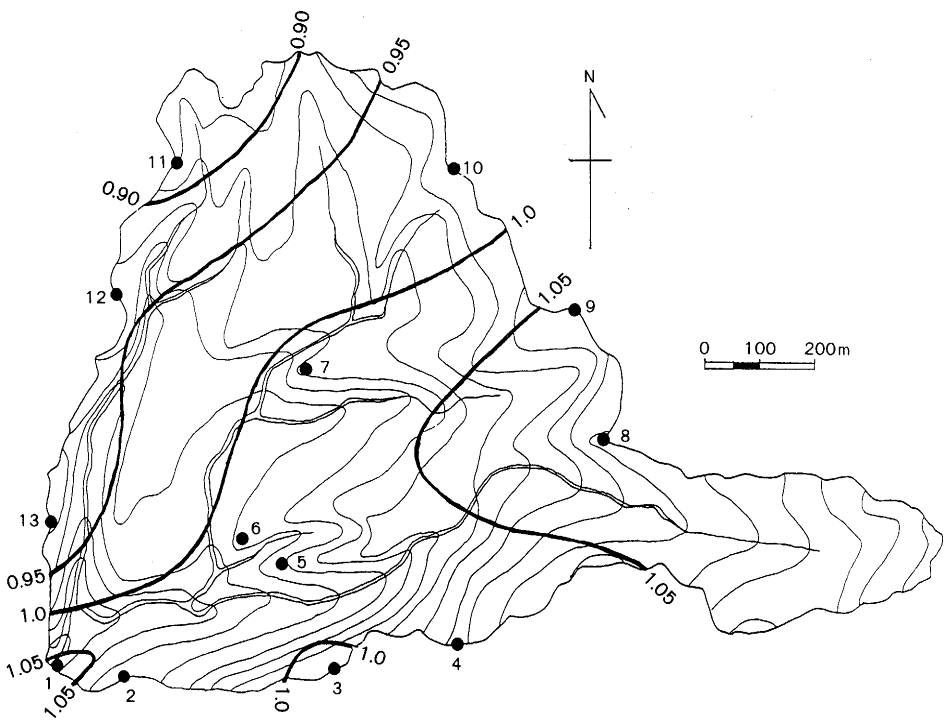

Fig. 1. Rainfall Distribution and Rain Stations.

every four or five days.

The map of Higashiyama Watershed and Rain Gauging Stations One to Thirteen is shown in Figure one.

Rain Station One is situated near the runoff gauging station and its data has represented the Higashiyama Watershed until now. Stations from Two to Four and from Eight to Thirteen are located on the ridge of the boundary-line of the Watershed and Stations from Five to Seven are located on small ridges in the centre of the area. Station Ten is on the bare land.

Each Station was set up carefully to avoid interference from big trees and topographical obstructions. The rain gauges were said to have no errors except those caused by the influence of the wind.

III. Results

Observed data from 1932 to 1947 was condensed into average monthly volume for each Station, and is shown in Table two.

AREAL RAINFALL OF THE WATERSHED: The most probable value of the AREAL RAINFALL was calculated by way of the arithmetic mean of the data of all the Stations, and is shown in Table two as "mean". Thiesen method was also tried and the results have no differences.

For each Rain Station, the ratois of annual and monthly rainfall values against those of Rain Station One were calculated. From this, the mean value and standard deviation for each was obtained and is shown in Table two.

The standard deviation M of the AREAL RAINFALL is calculated from that of each monthly rainfall m_i, as follows.

Table 2. Mean monthly rainfall of each station (1932–1947)

unit: mm

Station No.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	Annual	Rate for Mean
1	47.8	70.8	124.8	158.7	152.2	232.2	233.1	166.9	234.4	194.6	88.3	64.0	1767.8	1.054
2	44.2	66.6	119.3	151.0	146.8	223.6	224.9	161.7	225.2	185.9	84.4	57.1	1690.7	1.008
3	43.7	66.6	118.5	151.6	143.2	226.2	226.3	162.2	221.8	170.0	83.7	58.8	1672.9	0.998
4	46.7	68.5	120.4	153.0	150.5	230.3	230.0	166.3	225.0	185.0	85.2	60.6	1721.5	1.027
5	44.6	68.1	120.2	153.7	149.8	227.0	226.6	163.9	226.2	187.4	85.2	60.6	1713.3	1.022
6	46.8	70.3	123.3	155.9	151.3	228.1	226.6	166.4	225.7	188.0	86.3	62.3	1731.0	1.033
7	45.4	71.7	120.5	149.3	147.8	223.6	221.6	164.5	225.0	191.6	85.2	60.3	1706.5	1.018
8	49.2	71.5	129.3	162.4	159.5	235.3	238.4	171.6	231.6	193.2	88.3	62.4	1792.9	1.069
9	45.4	73.8	129.7	163.2	159.7	237.9	229.7	172.3	236.3	193.5	89.1	62.8	1793.4	1.070
10	40.4	66.4	115.1	143.4	139.2	216.6	199.2	163.3	217.4	184.0	82.7	57.8	1625.2	0.969
11	38.5	60.9	99.7	126.4	125.9	194.7	194.7	143.3	201.2	163.4	72.9	51.5	1473.1	0.870
12	41.8	67.0	109.6	135.7	133.8	210.7	208.6	151.6	210.3	178.8	77.8	57.8	1583.5	0.945
13	39.5	62.4	105.7	132.9	130.9	205.3	206.0	145.3	203.3	163.5	74.0	52.8	1521.6	0.908
Mean	44.2	68.0	118.2	149.0	145.4	222.4	220.4	161.5	221.8	183.0	83.3	59.1	1676.4	1.000
No. 1/Mean	1.082	1.042	1.056	1.065	1.041	1.044	1.057	1.033	1.057	1.063	1.060	1.082	1.055	

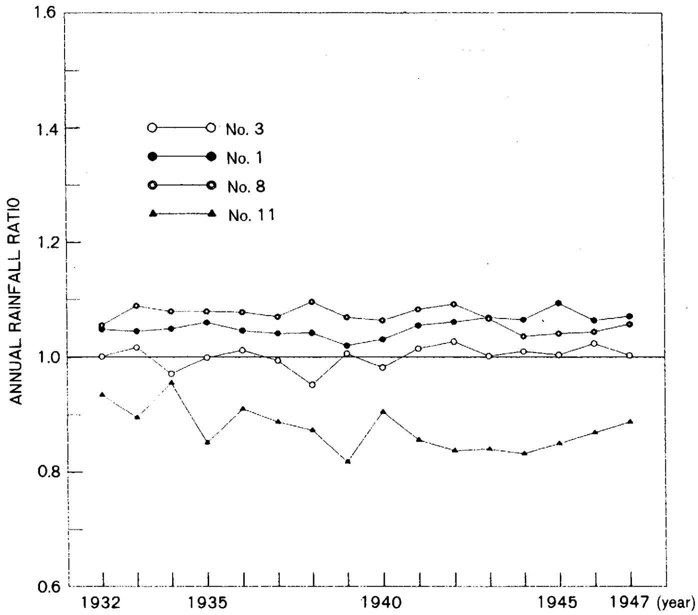

Fig. 2. Fluctuation of annual rainfall ratio.

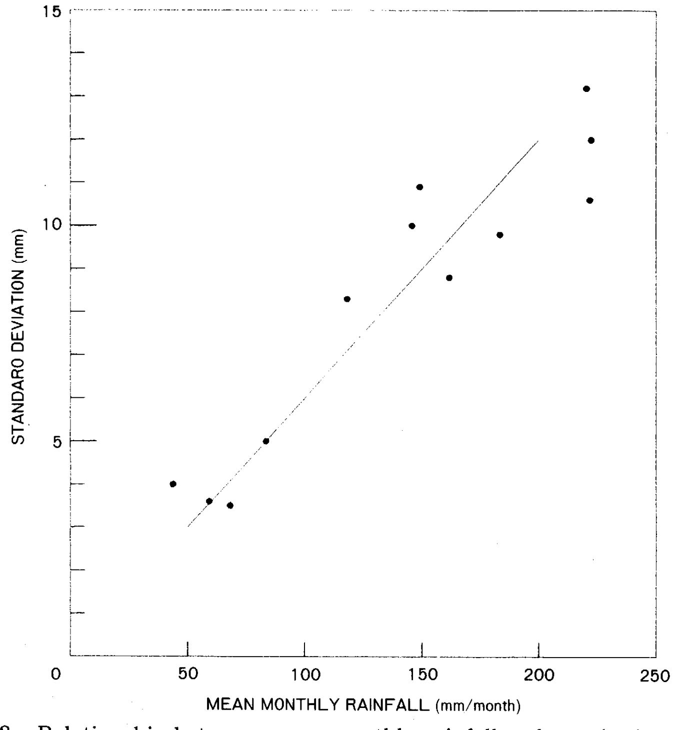

Fig. 3. Relationship between mean monthly rainfall and standard deviation.

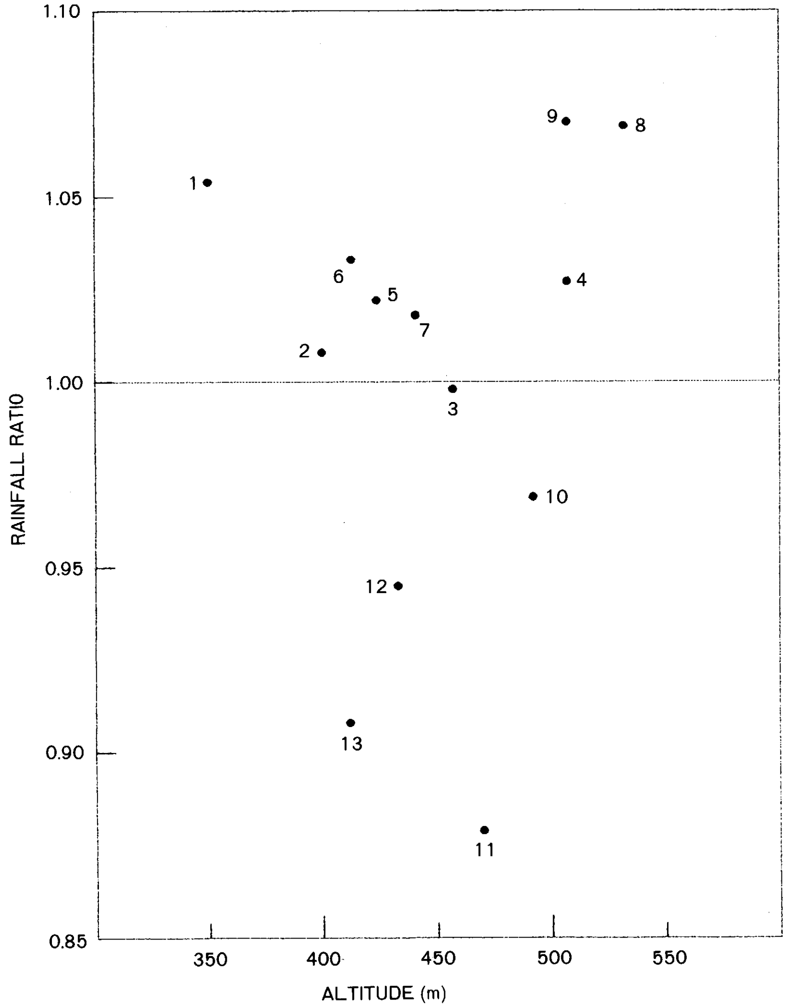

Fig. 4. Relationship between altitude and rainfall.

$$M=\frac{1}{13}(m_1{}^2+m_2{}^2+\cdots+m_{13}{}^2)^{1/2}$$

and is obtained as $M=0.020$

This means that when rainfall of Station One equalls to 1.000, the AERIAL RAINFALL calculated from the data of all Stations is 0.948 and its standard deviation is 0.020.

FLUCTUATION OF RAINFALL: Figure two shows the fluctuation of rainfall. This figure indicates that fluctuation of annual rainfall ratio in each observation point for annual AREAL RAINFALL. From this figure, we can lead to the following: fluctuation of rainfall in each station with regard to the volume has no change through the all duration of observation. Figure three shows the scatter with rainfall data in each point. In this figure, mean monthly rainfall of the horizontal axis is the areal monthly rainfall through all duration (from 1932 to 1947), and the vartical axis is the standard deviation. This figure indicates that the standard deviation correlates closely with mean monthly rainfall. The inclination of regression line is 0.06, and a correlation coefficient is 0.92. The inclination of

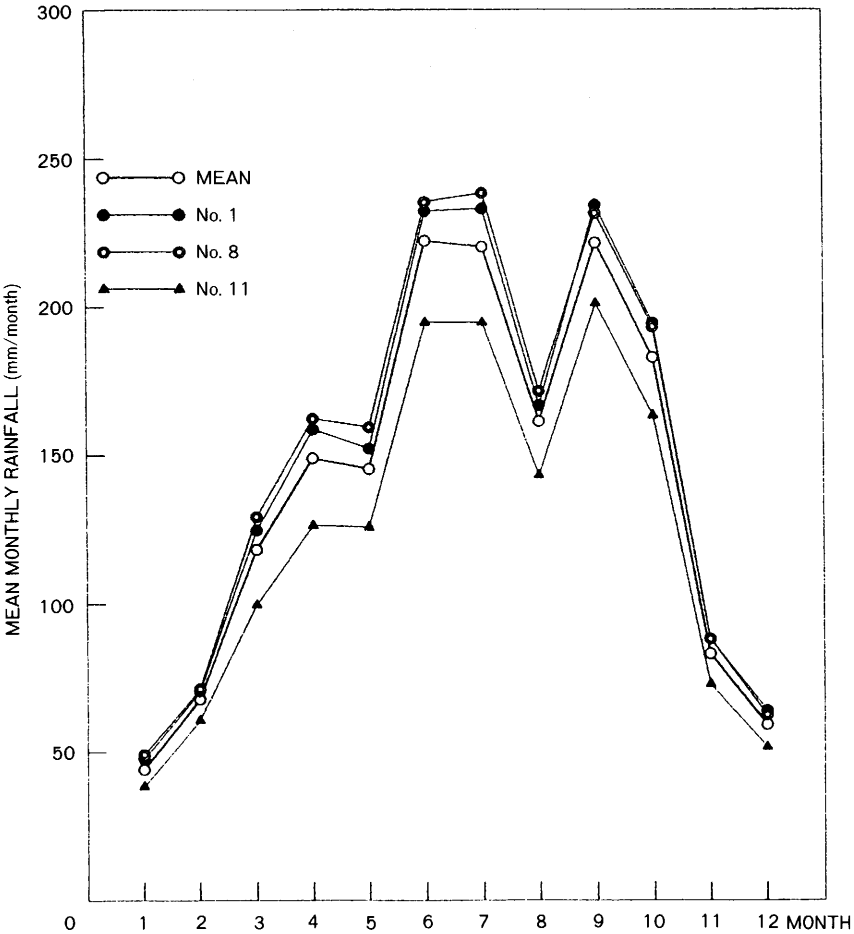

Fig. 5. Fluctuation of monthly rainfall.

this line means the scatter with rainfall data in each point. From this result, the scatter with rainfall data in each observation point is a certain fixed value through all duration.

RAINFALL DISTRIBUTION: The ratio of the annual rainfall values of each Station for the AREAL RAINFALL indicates the rain distribution in the watershed, and as shown in Figure one. In this figure, isohyet values are not absolute values, but ratios against the average volume. In the west part on the ridge of the basin, rain falls less than mean volume. At Station One, which is important for representing the watershed, and on the east part rain falls more than mean volume. The relationship between annual rainfall and the altitude of each Station is disrelated here, and shown in Fugure four.

The steady tendency for rainfall to decrease from north west to south east as is shown in Figure five does not change with the seasons. The cause of this tendency is difficult to determine but it may be caused by prevailing wind direction throughout the year.

REPRESENTATIVITY OF NO. 1: As mentioned above, data of Station One has long been used to represent the whole of Higashiyama Watershed, but has continually indicated 5.5 per cent more than the AREAL RAINFALL volume. The rainfall ratio of the AREAL

RAINFALL to Station One is 0.948 and its standard deviation is 0.040. Therefore,

random error = 0.027

mean error = 0.032

and the probabilities are,

95% on $0.870 < AR < 1.026$

99% on $0.845 < AR < 1.051$

AR: areal rainfall

IV. Summary

At Higashiyama Watershed high density rain gauging stations were set up and the observation was carried out from 1932 to 1947. In this study the quantity of rainfall measured at a representative gauging station was compared to the areal rainfall of the entire basin obtained from the data of thirteen stations. Though this watershed is small, there is a clear relationship between each station and a distribution map has been obtained. The result is that the volume of the areal rainfall is 0.948 times that of the representative station and its standard deviation is 0.040 when the volume of the representative value is 1.000.

Key words: Areal rainfall, Rainfall distribution, Representative rainfall of an area

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東山流域の降雨特性

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要　　旨

山地流域の降水量は地形条件と気象条件に影響されるので，点観測データから面積雨量を求めるとき誤差が生じる。本研究は東山流域内に高密度に設置した13箇所の，16年間の雨量観測資料から，流域の降雨分布特性を調べ，流域代表地点の雨量がどの程度流域の面積雨量を代表しているか，その精度を検討した。

月単位で集計した雨量データから，各雨量観測点について16年間の平均月雨量，年間雨量をもとめ，それらから算術平均法によって流域の面積雨量を得た。その精度は面積雨量を1.00とするとき，標準偏差は0.020である。

雨量分布は小面積ながら一定した大小関係の傾向を示し，流域代表地としての測点1の値を1.00とすると，流域面積雨量は0.948を示し，その標準偏差が0.040であることがわかった。

キーワード：面積雨量，雨量分布，流域代表雨量