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Hydrological processes and sediment yield on devastated slopes in JiangXi Province, China

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Abstract Over a three-year period the authors observed a devastated small forest watershed in JiangXi Province in southern China, to estimate rainfall, runoff and sediment yield. The observed watershed is in a hilly mountainous area, overlying weathered granite, and has many bare slopes and devastated forests. The devastation has increased due to indiscriminate cutting of trees, mowing of ground-cover, and raking up of fallen leaves for fuel. Precipitation in this area is concentrated in the summer rainy season from June to August. The authors analysed observed data primarily of rainfall, runoff and sediment yield. From the observations, it was noticed that there are two peaks of sediment discharge, one occurring in spring from April to May, and the other in the latter half of August. The earlier peak of sediment discharge is considered to be due to freezing and thawing, and the latter due to raindrop impact. The observed results were compared with data obtained from the experimental watersheds of the central part of Japan, and it was found that the sediment discharge rate observed in China is smaller than that of Japan. While their annual precipitation is nearly the same, and their geological conditions similar, their climate is quite different. In winter, the observed area of China has only 20–30 freezing days, whereas the comparable area in Japan has 60–100 days with a temperature below 0°C.

INTRODUCTION

The observed watershed is located near Dahou village of JiangXi Province in southern China (Fig. 1). The altitude of the watershed ranges from 340 to 420 m, and at the point of change in gradient of the slope there are many gullies in the basin filled with deposited sediment.

The watershed is divided into three small basins which are referred to as watersheds I, IV and V (Table 1). Figure 2 shows the topography of the watershed. In basins I, IV and V, the upper part of the slope is steep with gradients ranging from about 35° to 40°, and is covered with sparse vegetation of about 0.5 tree per m^2. The lower part of the slope is gentle with gradients ranging from 25° to 35° and with a density of vegetation of 0.8 trees per m^2 (Fig. 3).

Some experimental watersheds in the Tanakami region situated in the central part of Japan consist geologically of weathered granite. The Tanakami region is geographically, topographically and meteorologically similar to the Dahou region. For comparison to the observed watersheds in the Dahou Village, five Japanese

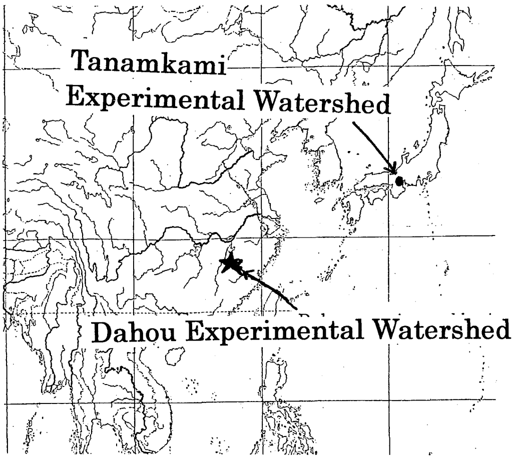

Fig. 1 Map of the experimental sites.

experimental watersheds named Rachi, Jyakujyo, Kiryu, Kawamukai and Nekoiwa were selected for observation. Their drainage areas and mean slopes are shown in Table 1. The mean annual temperature and the mean annual rainfall (1972–1977) were 12.5 and 1963 mm respectively (Biwako Work Office of the Ministry of Construction, 1981, 1985). The Rachi experimental watershed is bare land, where no reforestation has been carried out to date and closely resembles the Dahou watershed in many respects. In the other experimental watersheds in Japan, terracing has been introduced.

Table 1 Summary of properties in the experimental areas.

Experimental plots in Dahou:					
	I		IV	V	
Basin area (ha)	0.9		2.9	1.03	
Mean slope (°)	36.2		34.5	32.4	
Experimental plots in Tanakami region:					
	Jyakujyo	Rachi	Kiryu	Kawamukai	Nekoiwa
Basin area (ha)	2.88	0.18	5.99	2.66	0.01
Mean slope (°)	24.2	34.1	20.5	24.8	34.8

MONITORING APPROACH

As shown in Fig. 2, a raingauge has been installed in the watershed, a weir installed at the end of each watershed and a sediment trap is located on the upper side of each weir to measure sediment yield.

RESULTS AND DISCUSSION

Long-term runoff characteristics

Figure 4 shows the relationship between the total rainfall and the direct runoff for

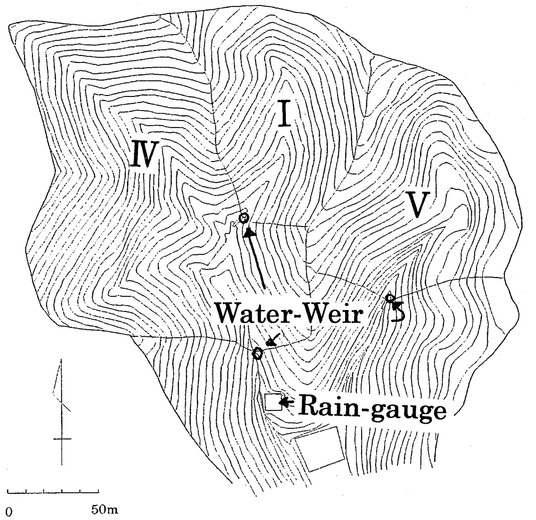

Fig. 2 Topography of the experimental watershed.

each flood occurrence. The Dahou watershed, compared with the Rachi and Kiryu watersheds, tends to be the largest in direct runoff for each flood occurrence. Moreover, the Dahou basin proves to be smaller in the dispersion of direct runoff *vs* total rainfall compared to that of the Rachi watershed.

Annual runoff *vs* rainfall characteristics

Figure 5 shows the annual runoff *vs* rainfall characteristics observed in the Dahou, Rachi and Kiryu watersheds. Firstly, bare lands such as the Dahou and Rachi

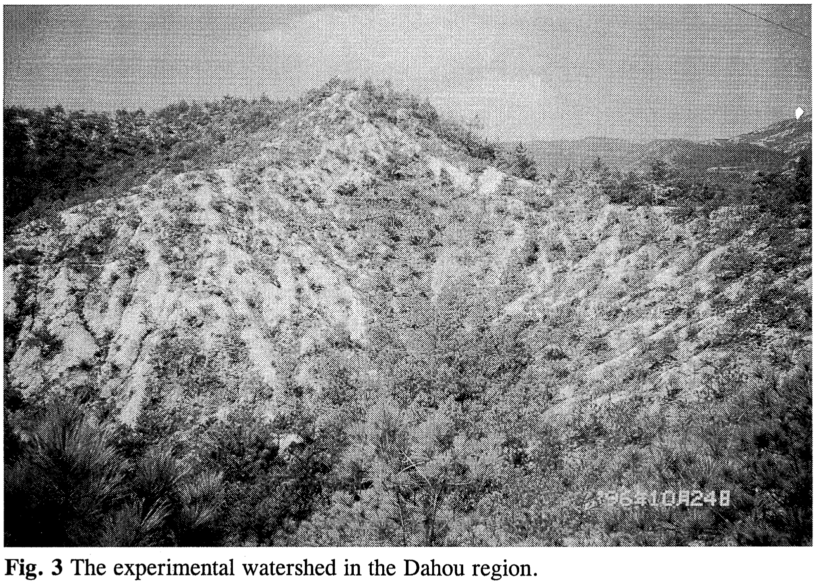

Fig. 3 The experimental watershed in the Dahou region.

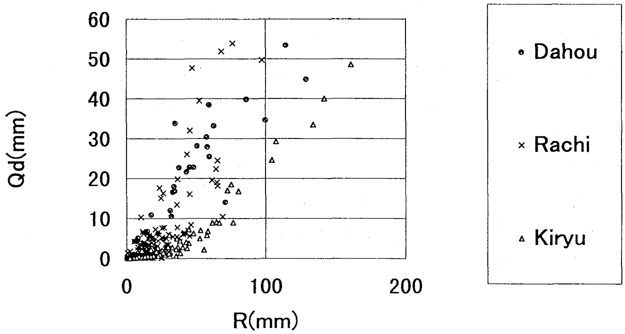

Fig. 4 The relationship between rainfall and direct runoff.

watersheds are higher in peak runoff than the forested Kiryu watershed. Secondly, noting the fluctuation of base runoff, it is seen that the Dahou watershed is different from the Rachi watershed in the decreasing process of base runoff. The Dahou region has a rainy season from April to June, during which about 40% of the annual rainfall occurs. In response to the rainfall the base runoff tends to increase moderately from June to July. This gradual annual fluctuation of base runoff suggests that the Dahou region has two types of runoff. One is the surface runoff which is a direct runoff component rapidly running off after rainfall. The other is the groundwater runoff presenting the base runoff component. This infiltrates deep into the ground to finally run off after a long period of time and it is considered the cause of the fluctuation of base runoff.

Next, noting the decreasing process of runoff after rainfall in the Dahou and Rachi watersheds, it can be seen that the runoff in the Dahou watershed decreases more sharply than that in the Rachi watershed. Such a phenomena in the Dahou watershed indicates that rainfall is predominantly and rapidly discharged as surface runoff. In contrast, such a rapid attenuation of runoff cannot be seen in the Rachi watershed. Furthermore, it is thought that the moderate runoff attenuation in the forested Kiryu watershed is a result of the well developed forest soil (Fukushima, 1987).

Sediment yield

Figure 6 shows the fluctuation of the total rainfall, sediment yield, and maximum rainfall intensity in the Dahou watershed as observed in 1995 through a time series of sediment measurements. It is seen from the figures that the sediment yield depends more on the maximum rainfall intensity than on the total rainfall.

The Dahou region encounters heavy rainfall in the period from April to May, in which the maximum hourly rainfalls on 16 April and 19 June were 26.8 and 24.0 mm respectively. These rainfalls are similar in scale, but their sediment yields are differ considerably being recorded as 82.0 and 44.7 m^3 km^{-2} respectively.

From April until early May in the observed watershed there is a tendency for even a relatively small rainfall to cause runoff of sediment, while in and after June the occurrence of a large rainfall is required to cause runoff of sediment.

Figure 7 shows the relationship between the maximum hourly rainfall and the sediment yield observed in a period of sediment measurement days in 1995 as shown in Fig. 6. From Fig. 7 it is evident that there is a tendency in April, regardless of rainfall intensity, for the sediment yield to be high. This means that in early spring a large level of sediment exists which has previously accumulated on the hillsides. According to meteorological observations taken from 1994 to 1995 the Dahou region has around 10–20 freezing days in winter. This suggests that there is the possibility that the freezing and thawing phenomena result in a high potential of easy movable sediment. After May the runoff of sediment is reduced with every rainfall, and it is strongly affected by the rainfall intensity. Such a correlation is further supported by

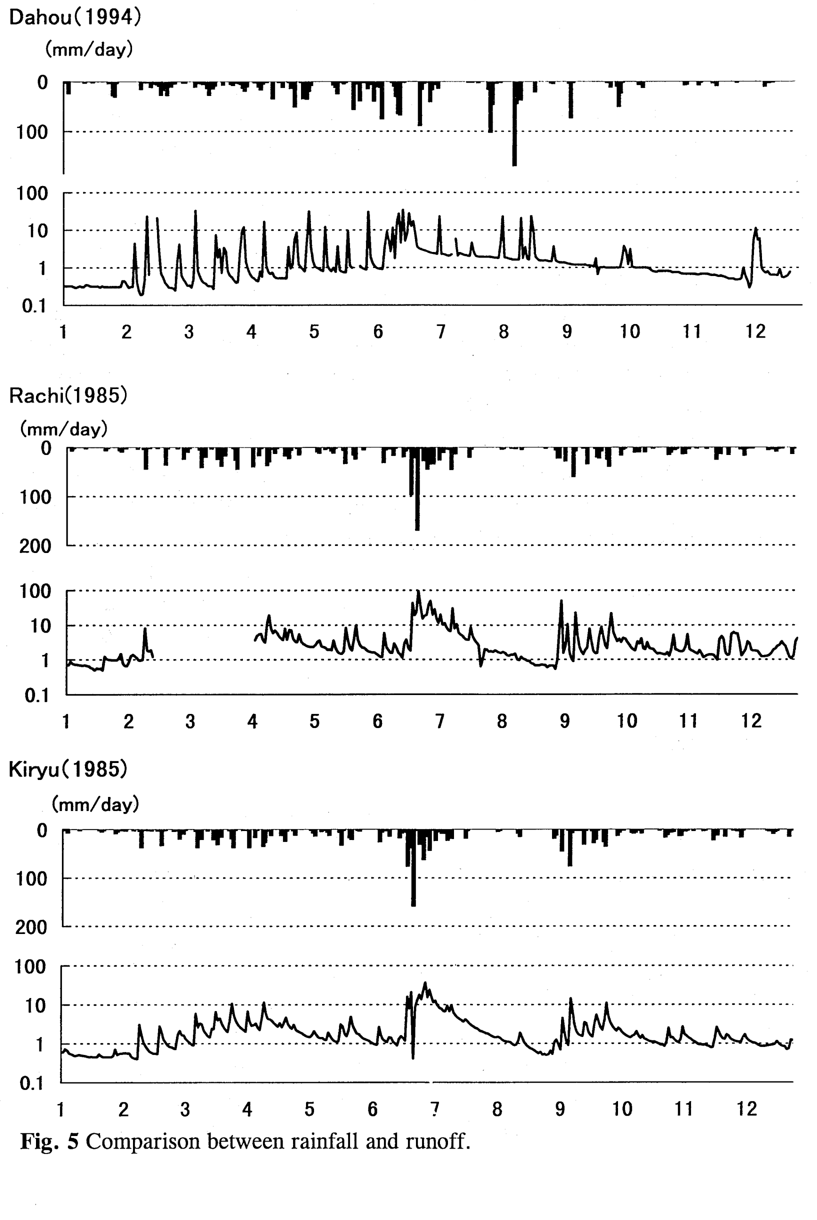

Fig. 5 Comparison between rainfall and runoff.

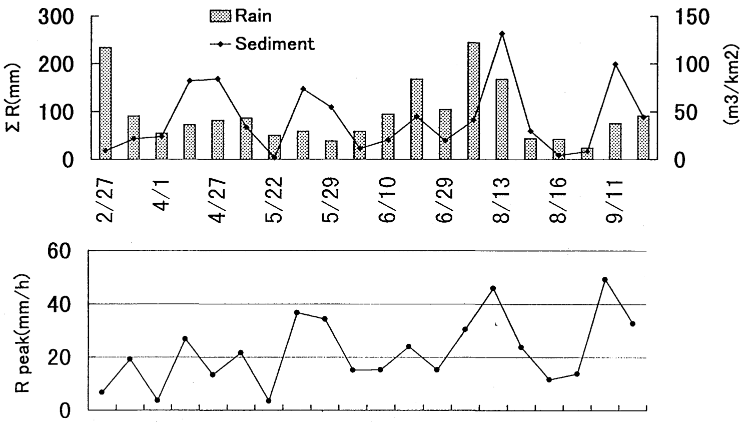

Fig. 6 The relationship between peak rainfall and peak runoff (1995).

the fact that as the rainfall intensity increases the sediment runoff increases, and that as the rainfall decreases the sediment runoff decreases.

Comparison of sediment yield between the Dahou region and the Tanakami mountainous region

Figure 8 is the result of a comparison between the sediment yield per unit area between the Dahou and Tanakami mountainous regions. The annual sediment yield of the Dahou region is 10% of that of the Rachi region, and 100 times that of the Kiryu region (based on Suzuki & Fukushima, 1989, with additional information from the authors). These differences are considered to be due to difference in area, winter temperature and weathering in the two regions.

In general as the area of a watershed increases, the slopes of the watershed become more gentle. This tendency towards gentle slope grade is considered to be a significant factor in the reduction of sediment yield.

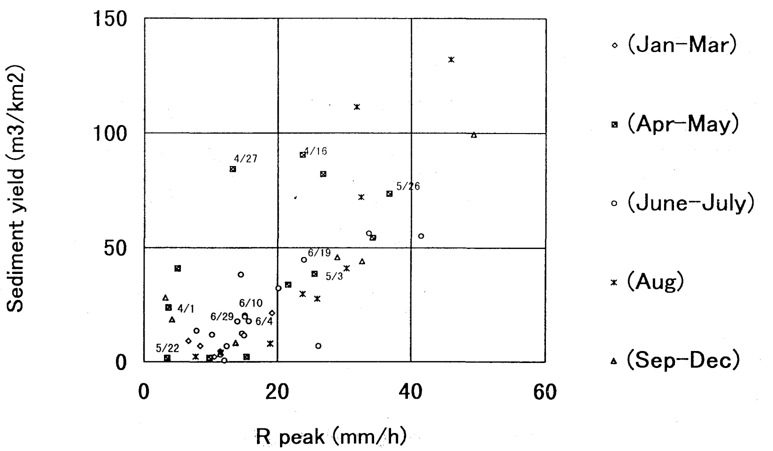

Fig. 7 The relationship between the maximum hourly rainfall and the sediment yield.

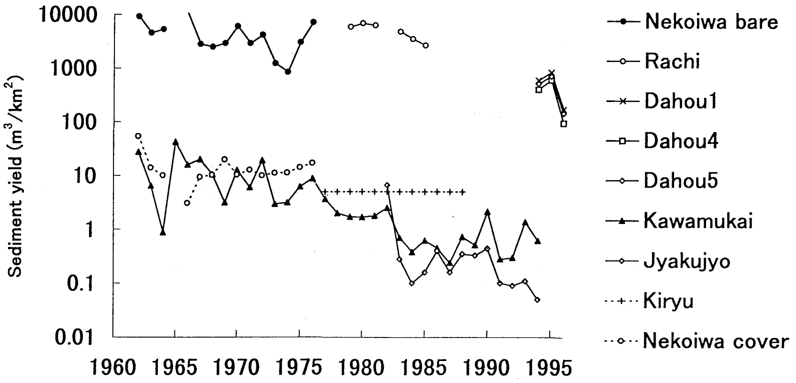

Fig. 8 Time series diagram of sediment yield based on Suzuki & Fukushima (1989) with additional information from the authors.

Next, the meteorological influence will be discussed. It has been proven from a number of reports that freezing and thawing have a great effect on the weakening and runoff of surface soil (Sawado & Takahashi, 1993). The Dahou region annually has fewer freezing days than the Tanakami mountainous region. It would be necessary to take into account the influence of this difference on soil erosion.

Finally, weathering conditions are reported to play an important role in soil erosion and there are various weathering parameters to define the weathering conditions. Although difficult, it is necessary to develop the method for evaluating weathering conditions.

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