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Article

Suspended sediment yield in a glaciated watershed of Langtang Valley, Nepal Himalayas.

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Abstract

The characteristics of suspended sediments and the annual suspended sediment yield have been investigated in Langtang Khola, Nepal Himalayas. The findings are as follows. Particles over 0.25 mm are contained only in the summer but the modal class for particle size ranges from 0.03 to 0.063 mm during the observed period. The particle size in Langtang Khola is finer than in the Tenjin River which does not have glaciers. The changes in concentration of suspended sediment correspond to water discharge. The relationships between water discharge and concentration of suspended sediment have hysteresis but the direction of the loops in these relationships is not uniform. The amount of suspended sediments is mostly proportional to the square of water discharge and the coefficient in this relationship is not so high in comparison to the values obtained in Japanese rivers. The annual suspended sediment yield and the rate of suspended sediment yield in this watershed are estimated at 30500 m^3 and 0.092 mm/year, respectively. It is also estimated that almost all of suspended sediments is discharged from June to September.

1. Introduction

Sediment yield is an indication of the rate of erosion in a drainage basin. If there is a glacier or are glaciers, their effects on erosion should not be ignored.

For the estimation of the annual suspended sediment yield, data of water discharge during a year are necessary. Measurements of water discharge in the Great Himalaya have been obtained (Nakawo *et al.*, 1976 ; Yamada *et al.*, 1984) during limited periods but have rarely been done continuounly for one year. So, the characteristics of suspended sediments have been unknown and the annual suspended sediment yield has not been estimated in Nepal Himalayas.

Nepalese and Japanese parties jointly investigated hydrological items in Langtang Valley from July 1985 to June 1986 and the measurement of suspended sediments was included in these items. In this report, the characteristics of suspended sediment discharge in Langtang Khola are analyzed and the annual suspended sediment yield in this watershed is estimated.

2. Studying Watershed and Measuring Methods

2. 1. Studying Watershed

Langtang Valley is located in the southern front of the Great Himalaya, some 100 km northward from Kathmandu and is the head area of the River Trisuli. There are three hydrological observation sites in this valley. One site is a large glaciated watershed, which is located on the main river of Langtang Valley, and the other two are small. In this report, suspended sediments in the main river are analyzed. This main river is called Langtang Khola in this report. The highest point of this watershed is about 7200 m a. s. l.

The hydrological observation site of Langtang Khola is located at 3840 m a. s. l. This station is a

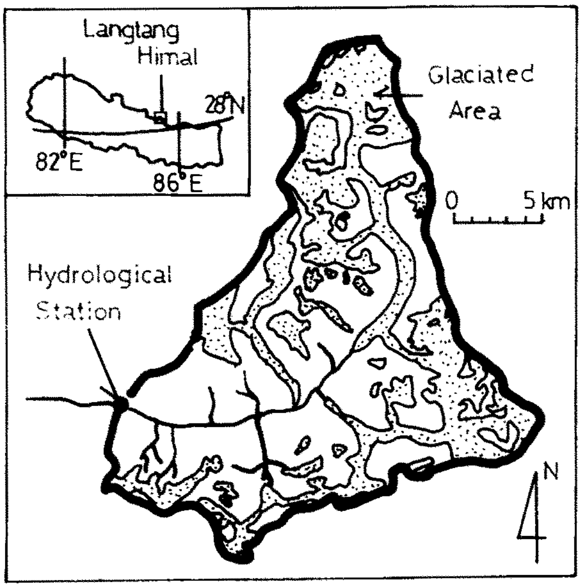

Fig. 1. The location of Langtang Himal in Nepal and the map of Langtang Khola watershed (Yamada, et al., 1984).

distance of 15 km from the end of Langtang Glacier which is a main glacier in this valley. The area of this watershed is 333 km^2 of which 127 km^2 is covered with glaciers. Figure 1 shows the location and the map of this watershed.

2. 2. Measuring Methods

Water discharge was recorded at the station from July 1985 to June 1986. Here, suspended sediments were sampled with water in bottles near the water surface from July 1985 to April 1986. The volume of sampled water was between 500 ml and 2000 ml in accordance with water discharge at the sampling times. During this measuring period, there were three measurements in which samplings were carried out every 1 to 4 hours during 24 hours.

Samples were filtered by filters, pore size being 4.5 $\times$ 10^{-4} mm. Then these samples were dried in the sun. In Japan, these filters with sediments were dried for 3 minutes in a microwave oven and their weight was measured. The weight of filters without sediments is same.

The analyses of the particle size of sediments are carried out by two methods. One is used for the particles over 0.25 mm. These particles are sifted. Another method is used for the particle under 0.25 mm. These particles are measured by the particle counter. In this method, the particles are separated every 5.0 $\times$ 10^{-3} mm.

The density of suspended sediment is assumed 2.65 g/cm^3 in this report.

3. Results and Discussions

3. 1. Distribution of Particle Size

The cumulative frequency curves of particle size distributions of suspended sediments and the relative frequency histograms are shown in Fig. 2 and Fig. 3, respectively. These figures show the results on one

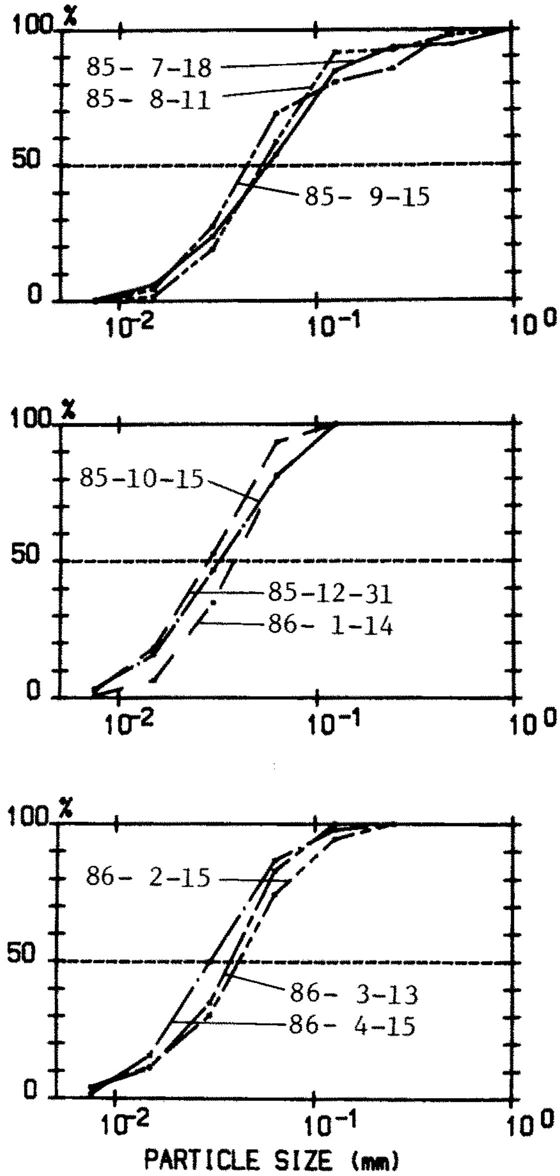

Fig. 2. The cumulative frequency curves of particle size distribution of suspended sediment.

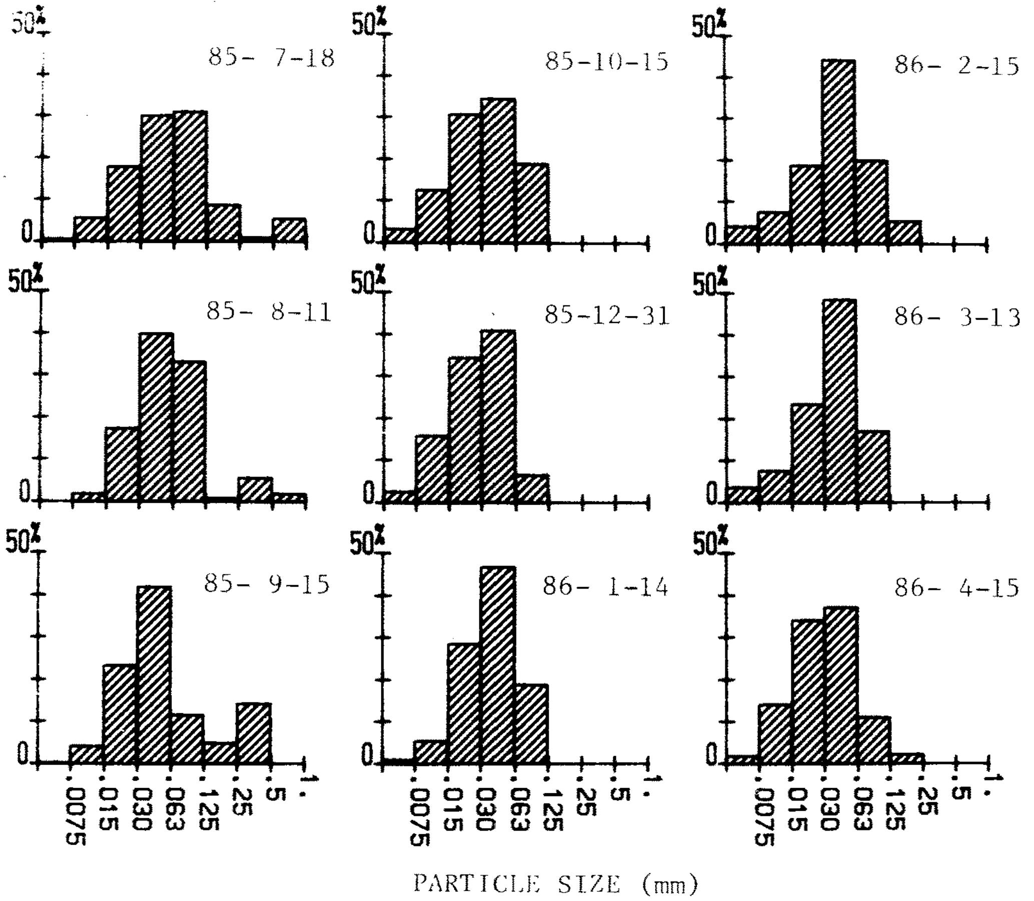

Fig. 3. The relative frequency histograms of particle size distributions of suspended sediment.

day. The hydrograph in this watershed does not change quickly and the change in water discharge during one day is similar in a season. So, the changes in the particle size distributions during the measureing period are discussed by these figures. It is found in Fig. 2 that there are two different types of the particle size distributions. Namely, the comparative large particles, over 0.25 mm, are contained in suspended sediments in July, August and September when water discharge is high, but these particles are not found in the other months. On the other hand, Fig. 3 indicates that the modal class occurs at the same particle size, from 0.03 to 0.063 mm, except in July and these classes contain 30 to 45 %. Even in July, the maximal values are shown in the size class from 0.063 to 0.125 mm and the difference between these two classes is small, so it is decided that the particles having sizes between 0.03 and 0.063 mm are contained most in Langtang Khola.

The particle size in Langtang Khola can be compared to the size of the Tenjin River in Japan. The Tenjin River is a mountainous watreshed in which there are no glaciers. It has been reported that all particles are under 0.15 mm in diameter when the water discharge is under 0.25 m^3/sec, and that the ratio of particles under 0.15 mm is decreased with the increase of water discharge and becomes constant, about 75 %, when the water discharge is over 0.6 m^3/sec (Ohta *et al.*, 1985). The 50th percentile median size of suspended sediments is distributed between 0.07 mm and 0.4 mm in the Tenjin River. On the other hand, the order of water discharge in Langtang Khola is 10^0 to 10^1 m^3/sec and higher than in the Tenjin River. But the percentage of particles under 0.15 mm exceeds 80 % even in summer and this value is over 95 % in other months. Figure 2 shows that the 50th percentile median size of the distribution is 0.03 mm to 0.05 mm. It is decided by these tendencies that suspended sediments in Langtang Khola is finer than in the Tenjin River. These results may be caused by differences of the processes producing fine particles. The fine particles will be produced by weathering in the Tenjin River. On the other hand, as glaciers exist in Langtang Khola, finer particles will be produced by the friction between the bottom of glaciers and the rock surface in addition to the weathering.

3. 2. Diurnal Changes in Concentration of Suspended Sediment

Figure 4 shows the changes in water discharge and in the concentration of suspended sediments during selected periods of 24 hours. The hydrographs of August and January are typical shapes on fine days in each season. The hydrograph of april is typical on cloudy days in winter or early spring and the changes in water discharge is very little. It is indicated that the wavy changes in the concentration correspond to water discharge in 3 seasons. The maximal concentration occured about the same time as the maximal discharge. This tendency is found in the minimal value, too. The minimal concentration occured from 6 : 00 to 9 : 00, because the minimal discharge occured at this time in all three measurements. The same tendency has been reported in Hidden Valley (Nakawo *et al.*, 1976).

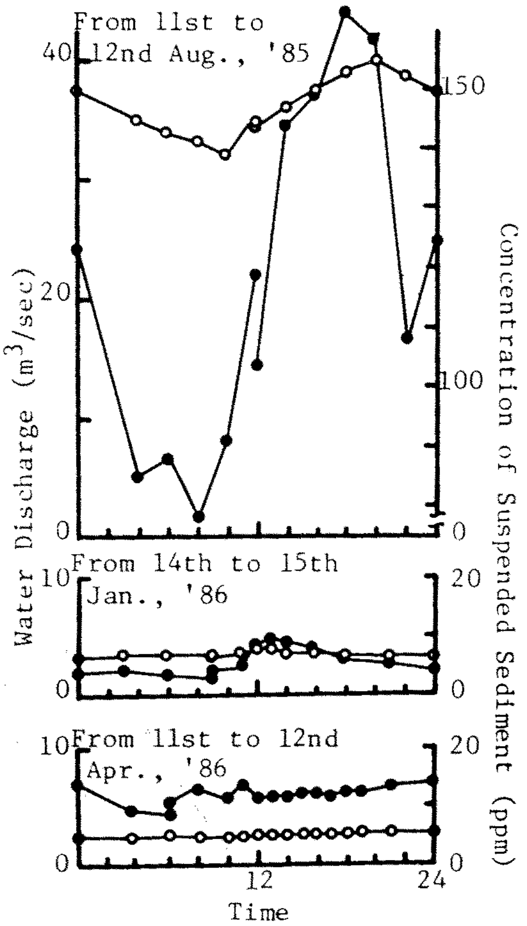

Fig. 4. The changes in water discharge and concentration of suspended sediments during 24 hours periods.
○: water discharge
●: concentration of suspended sediments

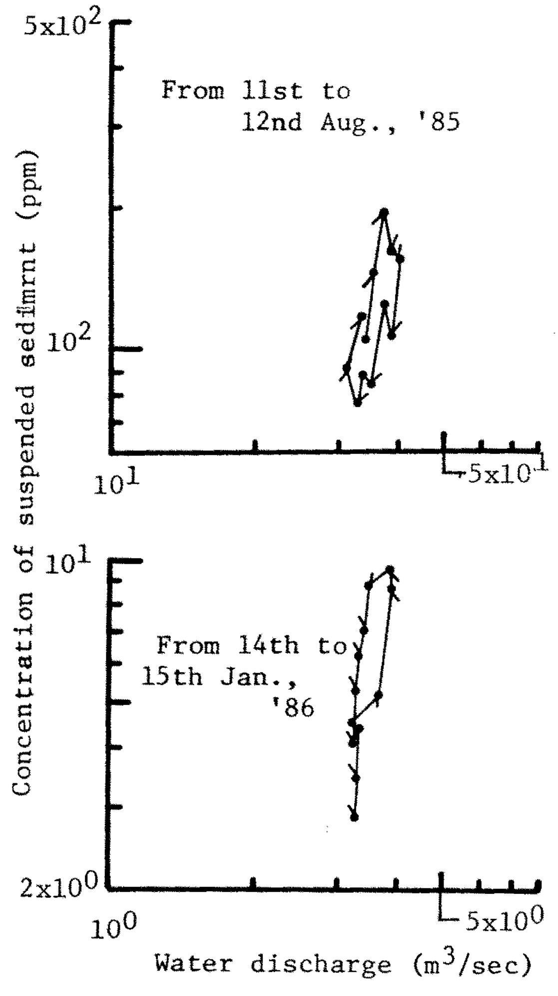

Fig. 5. The relationships between water discharge and concentration of suspended sediments during 24 hours periods.

Figure 5 shows the relationships between water discharge and the concentration of suspended sediments during 24 hours. It is known that the relationship has a hysteresis during each storm runoff in non-glaciated basin. The relationships indicate this tendency but the direction of the loops is opposite in August 1985 and January 1986. The relationship between water discharge and concentration of suspended sediments is empirically recognized as follows ;

$$C = K \cdot Q, \qquad (1)$$

where C is concentration of suspended sediments, Q is water discharge and K is a coefficient. But Fig. 5 shows that the value of a power in this relationship is more than 1.0 during short periods.

3. 3. *Relationship between Water Discharge and the Amount of Suspended Sediments*

The relationship between water discharge and the amount of suspended sediments is a base for the estimation of the annual suspended sediment yield. It is known that this relationship is described by

$$Qs = a \times Q^{M}, \qquad (2)$$

where Qs is the amount of discharged suspended sediments, Q is water discharge and a and M are the parameters which are decided in each watershed. It has been reported in many watersheds that the value of M in eq. (2) is about 2.0.

Figure 6 shows the relationship between Q and Qs in Langtang Khola. This relationship is expressed as :

$$Qs = 2.04 \times 10^{-6}\ Q^{2.05}, \qquad (3)$$

The numbers of these data are 114 measurements. The value of power, M, in eq. (3) is very close to 2.0. The amount of suspended sediments is proportional to the square of water discharge through the measureing period, though the value of M will be more than 2.0 during selected short periods, as described in 3.2.

The obtained coefficient, a, is not so high in comparison with the values obtained in Japanese rivers. It has been reported that the maximal order is 10^{-5} and that the average order is 10^{-7} (Muramoto *et al.*, 1975). The water of this river is very turbid, especially in summer, but the volume of suspended load is not large in quantity, because the particle size is small, as described above.

3. 4. *Estimation of Annual Suspended Sediment Yield*

In this section, the annual suspended sediment yield and the rate of suspended sediment yield in Langtang Khola are estimated by the relationship indicated in eq. (3). The data of water discharge was hourly data at the hydorological station of Langtang

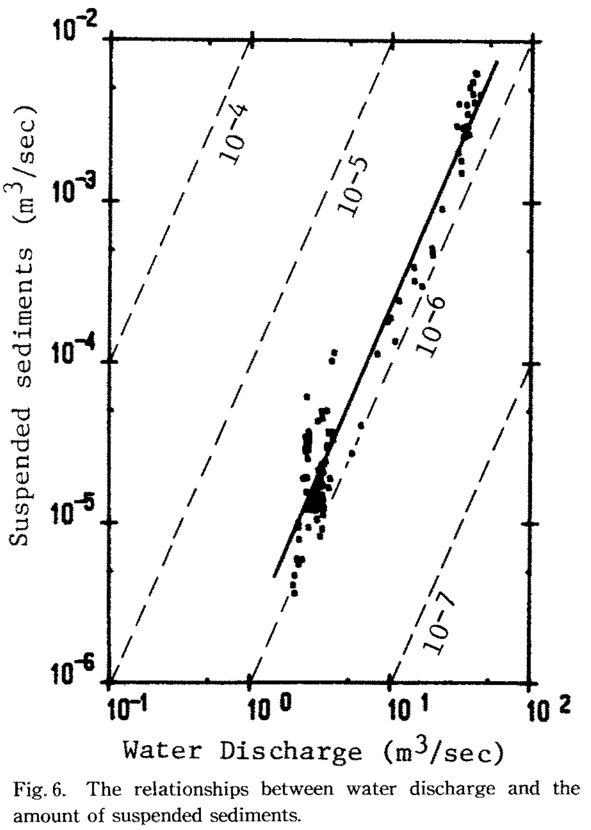

Fig. 6. The relationships between water discharge and the amount of suspended sediments.

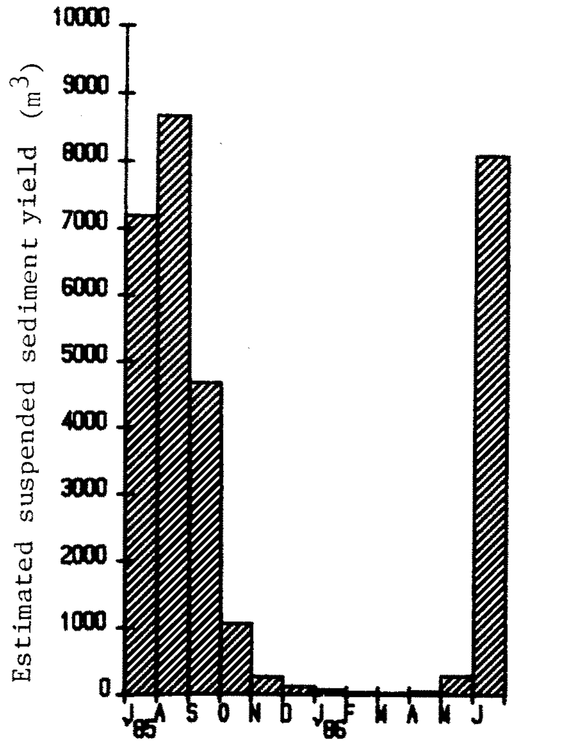

Fig. 7. The monthly suspended sediment yield estimated by eq. (3).

Khola. There were only 15 days during the one year, when water discharge could not be measured. Estimated values of water discharge are used for these 15 days.

The annual suspended sediment yield is estimated 30500 m^3 by eq. (3). Figure 7 shows the estimated suspended sediment yield in each month. It is found that suspended sediment yeild in June, July and August is very large and that it equals 78.6 % of the annual yield. Adding the suspended sediment yield in September to these three months, it is 93.9 % of the annual yield. It is estimated that almost all of the annual suspended sediments is discharged for these four months. On the other hand, the suspended sediment yield from December to April is no more than 1 % and it is considered that suspended sediments in these five months could be ignored in calculating the estimate of the annual sediment yield.

The rate of suspended sediment yield is estimated 0.092 mm/year in Langtang Khola. The hydrological station is far from the end of glaciers, so the rate of erosion of glaciers in Langtang Valley will be investigated by the data in the two small watersheds, hereafter. And the amount of traction load should be investigated for the estimate of the erosion rate.

4. Conclusion

In this report, the characteristics of suspended sediments are investigated and the annual suspended sediment yield is estimated in Langtang Khola.

Particles over 0.25 mm are contained only in summer and the mode of the particle size distribution was from 0.03 to 0.063 mm through the observed period. The particle size is finer in Langtang Khola than in the Tenjin River, Japan.

The changes in concentration of suspended sediments correspond to water discharge during 24 hours. The relationships between water discharge and concentration of suspended sediments during selected periods of 24 hours have hysteresis but the direction of the loops is not uniform.

The amount of suspended sediments is mostly proportional to the square of water discharge. The coefficient, a, in this relationship is not so high in comparison to the values obtained in Japanese rivers.

The annual suspended sediment yield in Langtang Khola is estimated at 30500 m^3 and almost all is discharged from June to Sepember in Langtang Khola. The rate of suspended sediment yield becomes 0.092 mm/year.

From now on, the following must be investigated. The first is the effect of the percentage of glaciers in a watershed on the suspended sediment yield in glaciered watersheds and the second is the rate of erosion of glaciers in Langtang Valley. The last is the estimation of traction load in this valley.

Acknowledgments

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