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海岸林学会誌 (*Journal of the Japanese Society of Coastal Forest*) 9 (1) : 11 – 14, 2010

Recurrence of sediment discharge in the riparian zone of a granite basin based on the analysis of terrace deposits in Kagoshima prefecture

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Abstract: To determine the recurrence of sediment discharge in the riparian zone of a granite basin in northwestern Kagoshima based on analysis of terrace deposits, aerial photograph interpretation, soil survey and soil profile analysis were carried out. Slope failure has occurred repeatedly in the basin. Slope failures were distributed mainly on slopes >30 degrees in the lower and middle reaches of the basin, and occurred both at sites of previous failures and sites where no previous failures have been observed. Number of sediment discharge events via bed load transport and debris flow was between 4 times and 7 times based on terrace deposit analysis, and relatively large-scale sediment discharges have also occurred several times. The recurrence of sediment discharge was correlated with slope failure in the basin.

1 Introduction

Much of the sediment produced by slope failures caused by heavy rainfall flows to the lower reaches of mountain basins via bed load transport and debris flows. The sediment transported by these processes often forms basin sand deposits, and consequently sand layers are considered to indicate the occurrence of slope failure and associated sediment discharge.

Development of the coast is closely concerned with sediment discharge caused by bed load transport and debris flows. Much sediment flowed to the coast area via debris flows caused considerable damage to the coast and the coastal forest. Therefore, in order to conserve the coast and the coastal forest, it is important to clarify the recurrence and characteristics of sediment discharge in the mountain basins.

Investigations of slope failure recurrence caused by heavy rainfall have been conducted by Shimokawa (1984), Yanai (1989) and Teramoto and Shimokawa (2008). Teramoto and Shimokawa (2008) used soil survey to study the recurrence of slope failure in a sedimentary rock basin in Kagoshima, and found that sand deposits provided depositional evidence of periodic slope failure. However, there are not many studies on slope failure recurrence and sediment discharge based on analysis of sand deposit.

The primary objective of this study is to determine the recurrence of sediment discharge in the riparian zone of a granite basin in northwestern Kagoshima based on terrace deposit analysis, using aerial photograph interpretation, soil survey and soil profile analysis.

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2 Study basin and methods

2.1 Study basin description

The study basin is located in the northwest of Kagoshima prefecture (Figure 1). The basin has an area of 0.56 km^2 and an altitude ranging from 445 m to 625 m above sea level. The drainage density of the basin was calculated using a 1/5000 topographical map, and the drainage system was defined using Strahler's method. The drainage density of the basin was 13.1 km/km^2. The average longitudinal slope of the basin was 5.4 degrees in the main stream channel (Teramoto *et al.*, 2005).

The slopes of the study basin was also calculated using the 1/5000 topographical map (Teramoto *et al.*, 2005), and the basin was classified into 10° intervals using the slope inclination distribution chart. 16.97% of the total area had slopes <10°, 24.78% had slopes 10-20°, 32.59% had slopes 20-30°, 14.08% had slopes 30-40°, and 11.58% had slopes >40°.

The geology of the study basin comprises granite, the surficial zone of which consists of grus caused by granite weathering. The grus has a thickness >20 m in the basin (Photo 1).

Photo 1: Grus observed in the study basin

The vegetation of the basin consists of laurel forest that occupies much of the area, and coniferous forest that occupies part of the basin valley floor.

2.2 Methods

Aerial photographs were used to characterize basin features and recurrence of slope failure, and a distribution chart detailing slope failure scars was produced. Seven pairs of aerial photographs taken in May 1973, March 1975, May 1984, October 1989, October 1993, March 1996, and March 2006 were used for the analysis. We also investigated basin geomorphology, and rainfall responsible for slope failure. Rainfall intensity assumed to be responsible for slope failure was defined as being >100 mm in one day. The rainfall analysis periods were May 1972 to May 1973 for the May 1973 aerial photograph, March 1974 to March 1975 for the March 1975 photograph, May 1983 to May 1984 for the May 1984 photograph, October 1988 to October 1989 for the October 1989 photograph, October 1992 to October 1993 for the October 1993 photograph, March 1995 to March 1996 for the March 1996 photograph taken in, and March 2005 to March 2006 for the March 2006 photograph. Rainfall data were recorded by an automated meteorological data acquisition system, which ran from 1973 to 2006 in the town of Miyanojyo (Miyanojyo automated meteorological data acquisition system, 1973-1975; Shibisan automated meteorological data acquisition system, 1983-2006).

A soil survey was conducted and six reference soil profiles were described (Figure 1, Photo 2) and their tone and mode of deposition characterized. Soil samples were collected from each soil horizon and were used to determine grain size distribution, uniformity coefficient and coefficient of curvature (Kawakami, 1983). Recurrence of sediment discharge was investigated using the results of the soil survey, sample analysis and known timing of slope failure through aerial photograph interpretation.

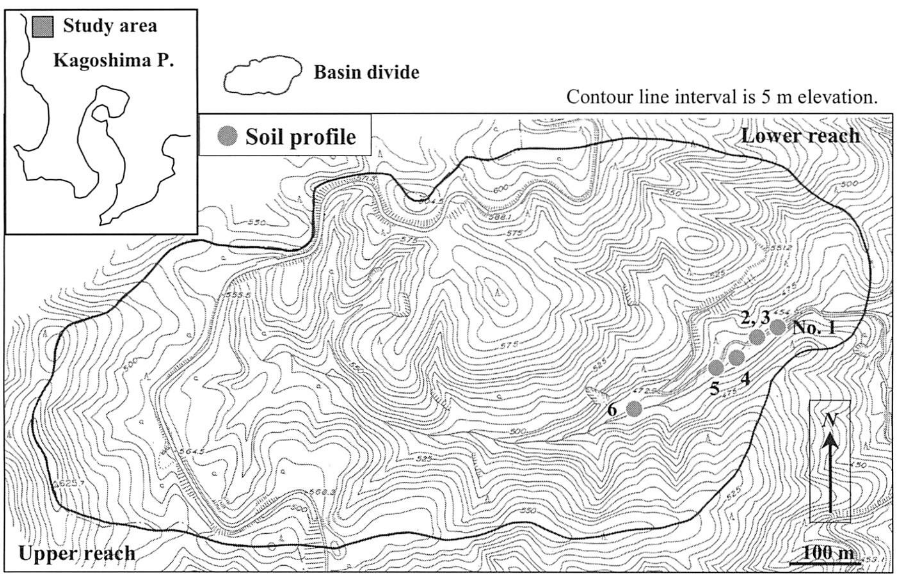

Figure 1: Location of the study basin

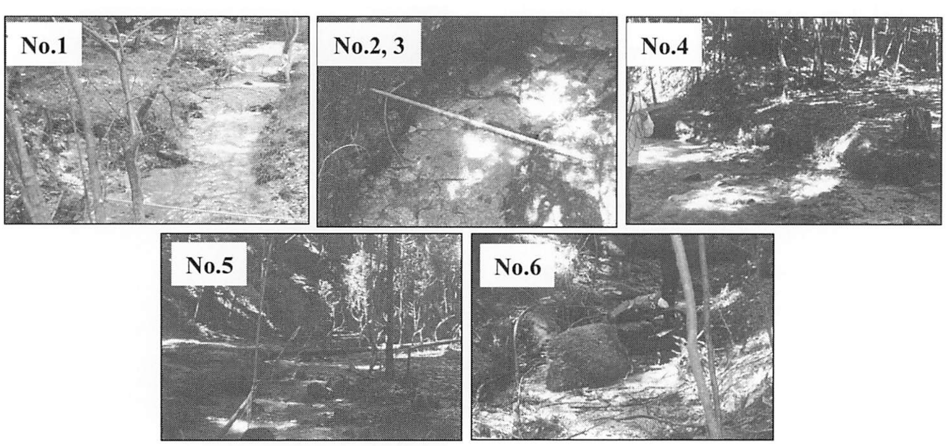

Photo 2: Locations of soil survey points

3 Results and discussion

3.1 Features and recurrence of slope failure

Figure 2 shows a distribution chart of slope failure scars interpreted from the aerial photographs of the study basin. Forty-nine slope failures were detected, and were distributed mainly on the lower and middle basin reaches. Failures included both shallow landslides and debris flows which occurred mainly on slopes >30°. Shallow landslides resulted from rain water infiltration of into the soil surface and its concentration in cuttings and natural slopes. Slope failures occurred both at sites of previous failures and sites where no previous failures have been observed. Shimokawa (1984) noted the recurrence of slope failure in the steep slopes of the granite basin.

The numbers of days on which rainfall >100 mm were 7 in the period from May 1972 to May 1973, 1 in the period from March 1974 to March 1975, 3 in the period from May 1983 to May 1984, 5 in the period from October 1988 to October 1989, 15 in the period from October 1992 to October 1993, 4 in the period from March 1995 to March 1996, and 3 in the period from March 2005 to March 2006.

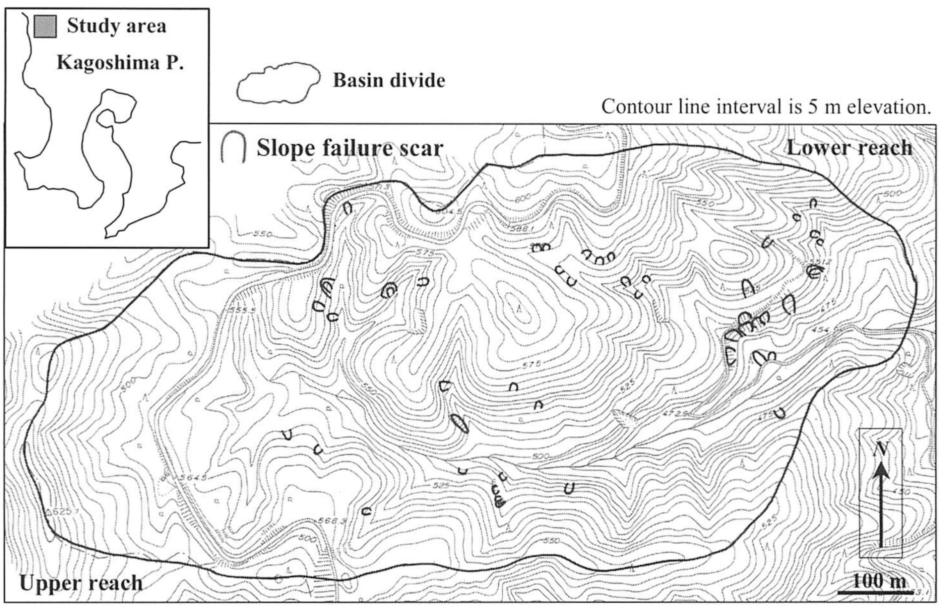

Figure 2: Distribution chart of slope failure scars from the interpretation of aerial photographs

3.2 Sediment discharge recurrence of based on terrace deposit analysis

Figure 3 shows soil profile No. 1 with median grain diameter, uniformity coefficient and coefficient of curvature for each soil horizon. Several terrace deposits contain multiple sand layers as evidenced by grain size. This suggests that much of the sediment produced by slope failures has been redistributed via bed load transport and debris flows in the basin.

Figure 4 shows terrace soil profiles 1 to 6 (see also Figure 1). We estimated the recurrence of sediment discharge based on the tone, deposition conditions and grain features of the terrace deposits. The numbers of sediment discharge events for each terrace, based on stratigraphic analysis, were 4 times in No. 5 and No. 6, 5 times in No. 3 and No. 4, 6 times in No. 2, and 7 times in No. 1. Moreover, the same individual sand units were observed on all terraces, which indicated that large-scale sediment discharges have flowed across all terrace surfaces in the basin several times. The sediment discharge recurrence was correlated with the timing of

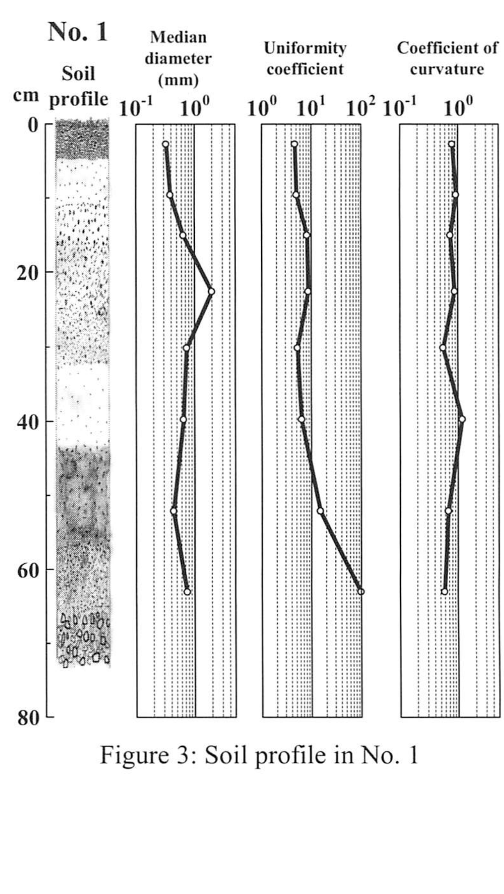

Figure 3: Soil profile in No. 1

slope failures identified in the aerial photograph interpretation.

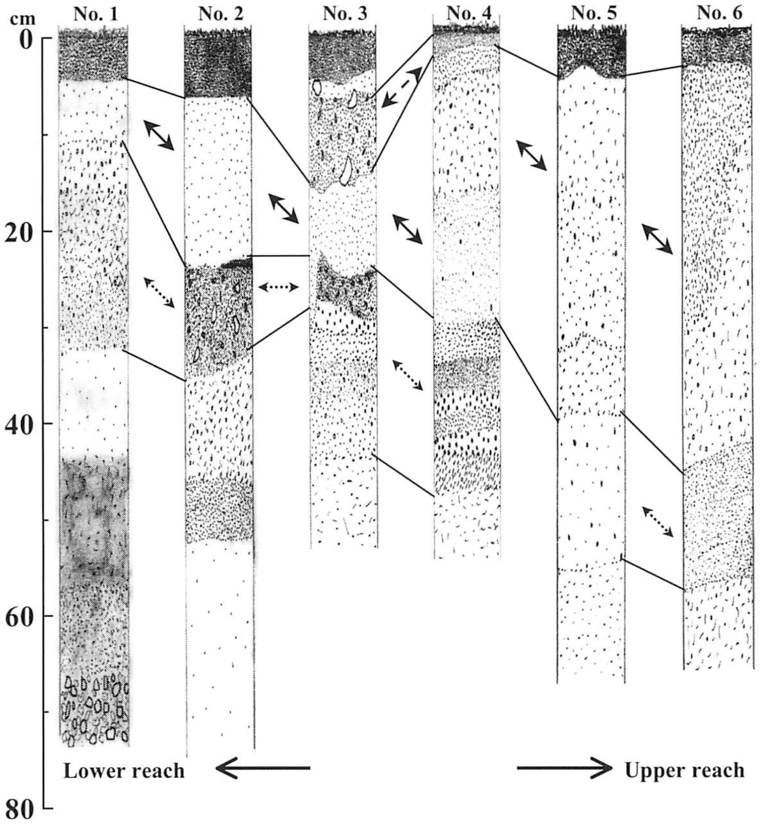

Figure 4: Recurrence of occurrence of sediment discharge based on the analysis of the terrace deposits

4 Conclusions

The results of the present study were:.

(1) Slope failures in the basin included both shallow landslides and debris flows which occurred mainly on slopes >30°. Shallow landslides resulted from rain water infiltration of into the soil surface and its concentration in cuttings and natural slopes. Slope failure in the basin has occurred repeatedly.

(2) The number of sediment discharge events in the study basin via bed load transport and debris flows was between 4 times and 7 times on the basis of terrace deposit analysis. The sediment discharge recurrence was correlated with the timing of slope failures identified in aerial photograph interpretation.

Acknowledgments

The authors would like to express their appreciation of the cooperation of students of the Erosion Control Engineering and Forest Hydrology Laboratory at the Faculty of Agriculture, Kagoshima University.

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〔Received January 29th,2009 Accepted May 7th, 2010〕