Original Article

Damage caused by typhoon Nabi to slopes bordering forest roads in the Takakuma Experimental Forest, Kagoshima University, in September 2005

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Summary

In order to clarify the nature and scale of the damage caused by typhoon Nabi in September 2005 to the slopes bordering the forest road through the Takakuma Experimental Forest at Kagoshima University, thirty five slopes bordering the road, damaged by typhoon Nabi, were investigated. Characteristic results were as follows:

(1) The geological composition of the study area is a sandstone and shale base, overlaid with pyroclastic fall and pyroclastic flow deposits, volcanic ash and volcanic pumice originating from eruptions of the Sakurajima Volcano. Several types of erosion and slope failure were observed within the study area.: slope failure occurring on the downhill side of the forest road, as a result of the combined effect of groundwater from between the bedrock and the pyroclastic fall deposits being augmented by an influx of rain water; shallow landslide resulting from the infiltration and concentration of rain water into surface soil in the cutting and natural slope; deep-seated landslide resulting from groundwater between the bedrock and pyroclastic fall deposits combining with an influx of rain water; failure of the subbase and subgrade bearing body of the forest road itself, as a result of groundwater between the bedrock and pyroclastic fall deposits together with an influx of rain water; and the clogging of conduits and partial failure of the forest roads themselves, as a result of inundation by sediments due to debris flow.

(2) Areas of slope failure and sediment yields resulting from slope failure within the study area were investigated. The area of slope failure ranged from 16 m^2 to 400 m^2 (average 133 m^2) and the sediment yield due to slope failure ranged from 10 m^3 to 1,600 m^3 (average 223 m^3). The following figures obtained in one particular area of slope failure and sediment yield were obtained slope failure occurring on the downhill side of the forest road; deep-seated landslide; and failure of the subbase and subgrade bearing body of the forest road itself showed a big value comparing with types of other erosion and slope failure within the study area.

Key Words: Typhoon Nabi, Takakuma Experimental Forest at Kagoshima University, slopes bordering the forest roads, nature of damage

1. Introduction

The sediment-related disaster of typhoon Nabi extended over a wide area of Kyushu, Chugoku and Shikoku from 6th to 7th September, 2005. A total rainfall of at least 600 mm fell between 4th and 6th September, 2005 (Takatoge automated meteorological data acquisition system, 2005), resulting in slope failures and frequent debris and mud flows in Kagoshima Prefecture, especially on the Osumi peninsula. Five people died in the disaster, and considerable damage was caused to houses, engineering works and the agricultural, forestry and fishing industries of Kagoshima Prefecture, particularly in Tarumizu City. In addition, the typhoon brought traffic on the national road passing through Tarumizu City to a complete halt owing to the large amount of sediment, and one village was temporarily cut off (Taniguchi et al., 2005).

Typhoon Nabi caused considerable damage to the slopes bordering the forest roads in the Takakuma Experimental Forest at Kagoshima University. As a result, part of the road passing through the Takakuma Experimental Forest became completely impassable. Damage to the forest roads has occurred before in the Takakuma Experimental Forest, in 1997 and 2004 (Ashihara et al., 2005), but the scale of the damage caused by typhoon Nabi was much larger than on those two previous occasions.

The authors carried out a field investigation of the slopes bordering the forest road in the Takakuma Experimental Forest at Kagoshima University in Tarumizu City in order to clarify the nature and scale of the damage done by typhoon Nabi. The results of this investigation are presented and discussed below.

2. Rainfall generated by typhoon Nabi in the Takakuma Experimental Forest

Rain falling from September 4th to 6th 2005, as a consequence of typhoon Nabi, was recorded by a Takatoge automated meteorological data acquisition system, which revealed that the maximum hourly rainfall was 38 mm. Furthermore, the total rainfall reached 600 mm or more. Heavy rainfall due to typhoon Nabi continued for a comparatively long time (Takatoge automated meteorological data acquisition system, 2005).

3. Study area and method

The study area encompassed slopes both above and below the

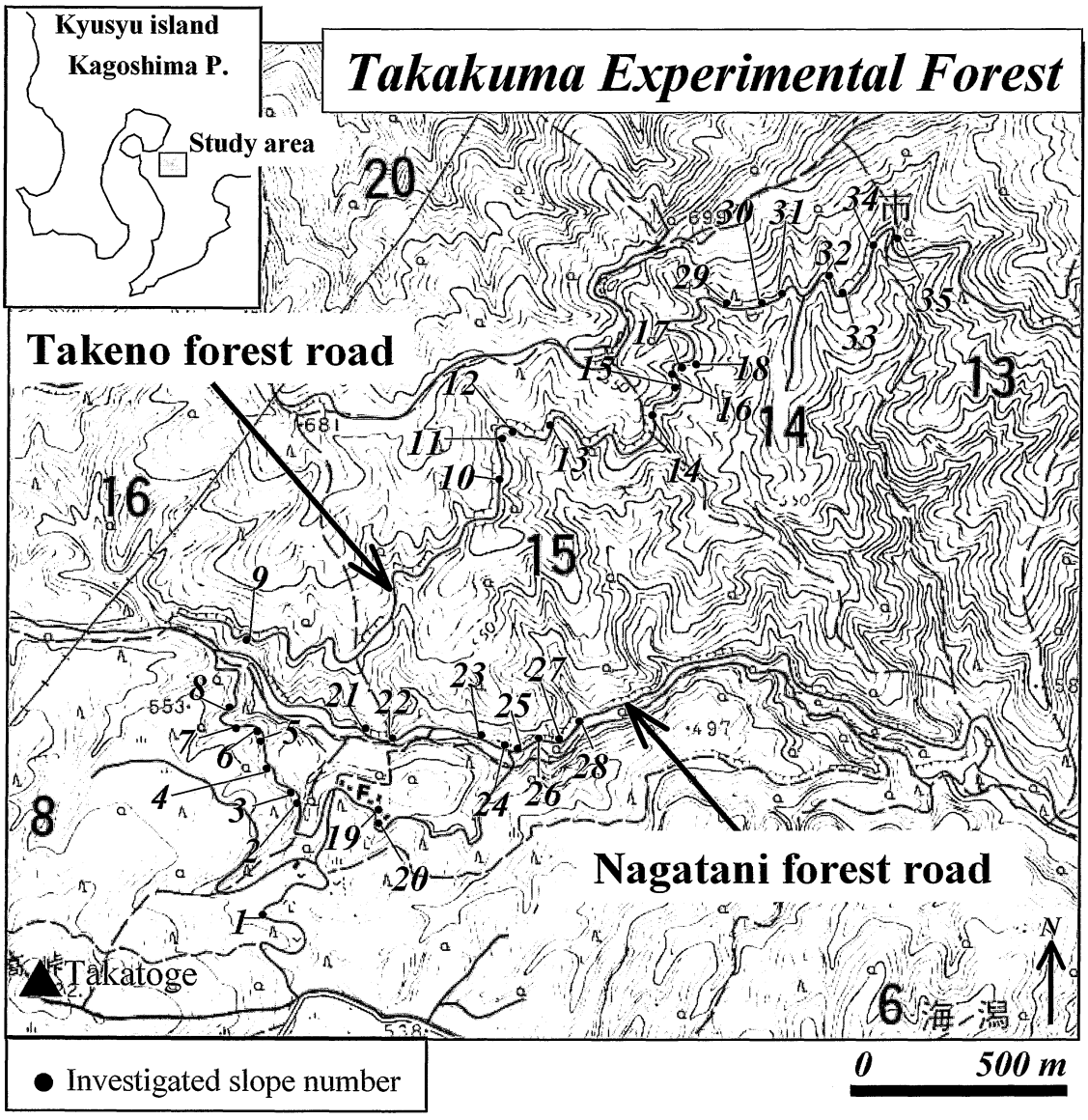


Fig. 1 Location of the study area.

forest road within the Takakuma Experimental Forest at Kagoshima University in Tarumizu City, situated to the east of Sakurajima Volcano (**Fig. 1**). Thirty five sample slopes bordering the forest road and damaged by typhoon Nabi were investigated (Fig. 1). To clarify the nature and scale of the damage experienced by the slopes, we investigated the following: form of slope failure; geological and geomorphological features; presence of spring water; shape of slope; inclination of slope; vegetation; area of slope failure; and sediment yield due to slope failure. The sediment yield due to slope failure was calculated from the area and effective depth of slope failure measured in the field investigation.

The geological composition of the study area is sandstone and shale, overlaid with pyroclastic fall and pyroclastic flow deposits, volcanic ash and volcanic pumice, resulting from successive eruptions of the Sakurajima Volcano.

4. Types of damage to the slopes bordering the forest roads in the Takakuma Experimental Forest

We shall now describe the types of erosion and slope failure observed within the study area.

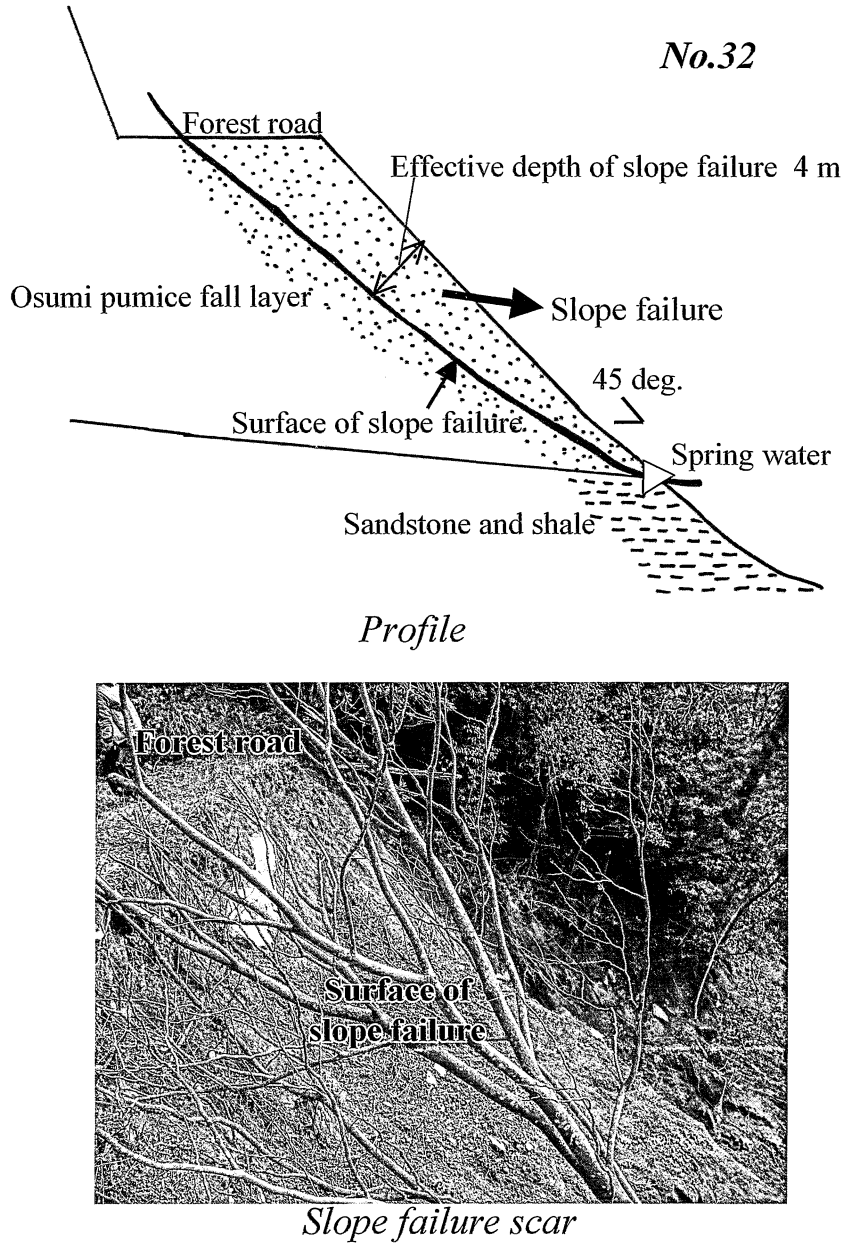


Fig. 2 Pattern diagrams and state of erosion and slope failure observed at sample point No.32.

Fig. 2 shows pattern diagrams and key features of the erosion and slope failure observed at sample point No.32 in Fig. 1. This slope failure was a slope failure occurring on the downhill side of the forest road as a result of groundwater between the bedrock (sandstone and shale) and the pyroclastic fall deposits (Osumi pumice fall layer) being augmented by an influx of rain water. The width of the slope failure was 20 m, with a slope length of 20 m, and an effective depth of slope failure of 4 m. The area of slope failure was, therefore, 400 m^2 and the sediment yield due to slope failure was 1,600 m^3. The magnitude demonstrated by this slope failure had the highest value of any within the study area.

Fig. 3 shows pattern diagrams and key features of the erosion and slope failure observed at sample point No.2 in Fig. 1. This slope failure was a shallow landslide resulting from the infiltration and concentration of rain water into surface soil in the cutting slope. The width of slope failure was 5 m, with a slope length of 8 m, and an effective depth of slope failure of 0.5 m. Thus, the area of slope failure was 40 m^2, and the sediment yield due to slope failure was 20 m^3. This type of slope failure was on a small scale, when compared with others within the study area.

Fig. 4 shows pattern diagrams and key features of the erosion and slope failure observed at sample point No.25 in Fig. 1. This slope failure was a shallow landslide resulting from the infiltration and concentration of rain water into surface soil in the natural slope. The width of slope failure was 10 m, with a slope length of 25 m, and an effective depth of slope failure of 1 m. Thus, the area of slope failure was 250 m^2, and the sediment

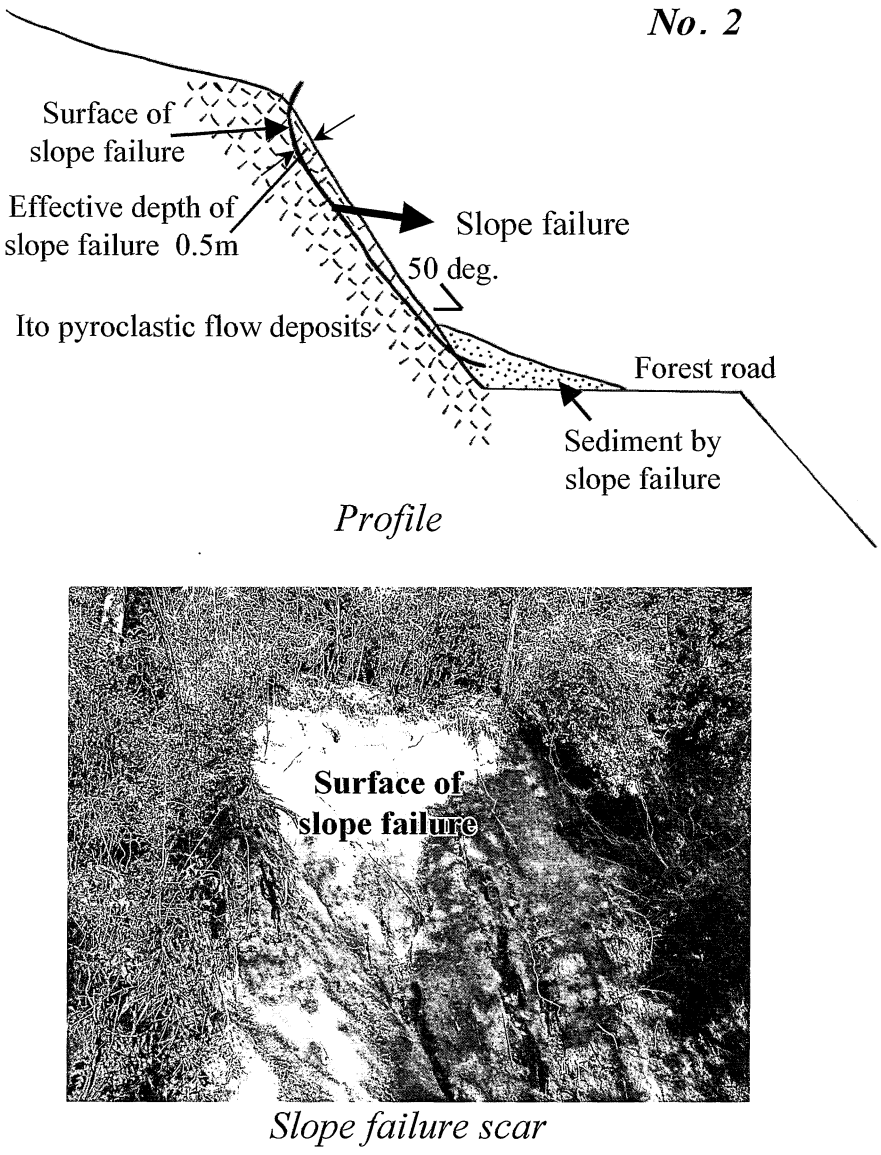
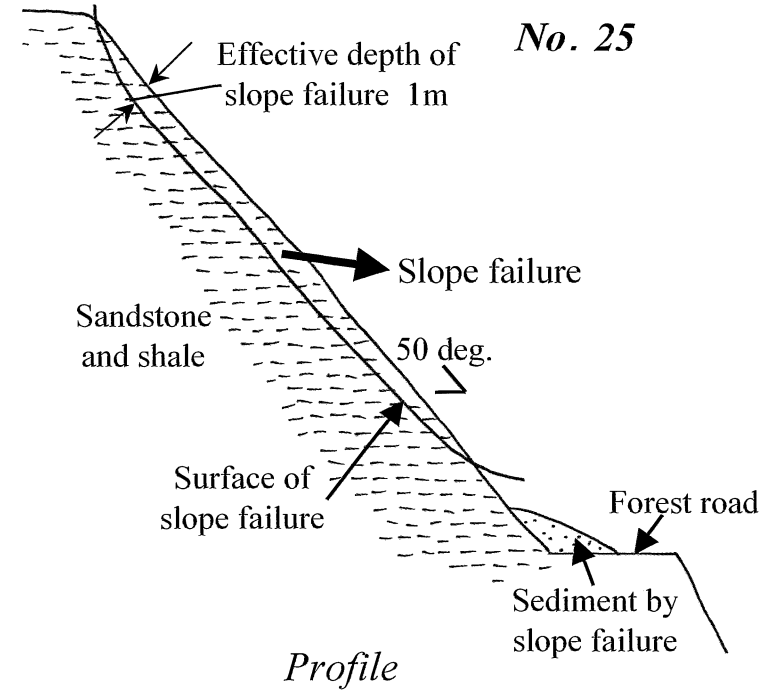


Fig. 3 Pattern diagrams and state of erosion and slope failure observed at sample point No.2.

yield due to slope failure was 250 m^3. The magnitude of this slope failure was relatively large, when compared with other shallow landslides within in the study area.

Fig. 5 shows pattern diagrams and key features of the erosion and slope failure observed at sample point No.31 in Fig. 1. This slope failure was a deep-seated landslide resulting from groundwater between the bedrock (sandstone and shale) and the overlying pyroclastic fall deposits (Osumi pumice fall layer) augmented by an influx of rain water. The width of slope failure was 20 m, with a slope length of 16 m, and an effective depth of slope failure of 2 m. Thus, the area of slope failure was 320 m^2, and the sediment yield due to slope failure was 640 m^3.

Fig. 6 shows pattern diagrams and key features of the erosion and slope failure observed at sample point No.10 in Fig. 1. This slope failure was a failure of the subbase and subgrade bearing body of the forest road itself, as a result of groundwater between the bedrock (sandstone and shale) and the pyroclastic fall deposits (Osumi pumice fall layer) augmented by an influx of rain



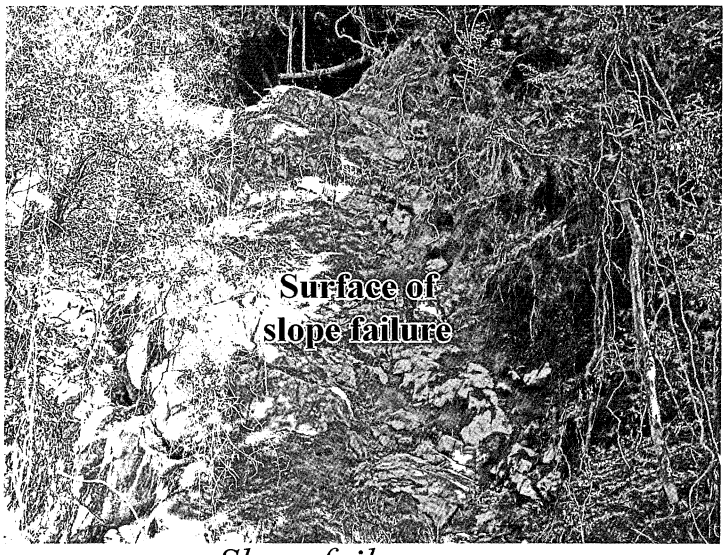
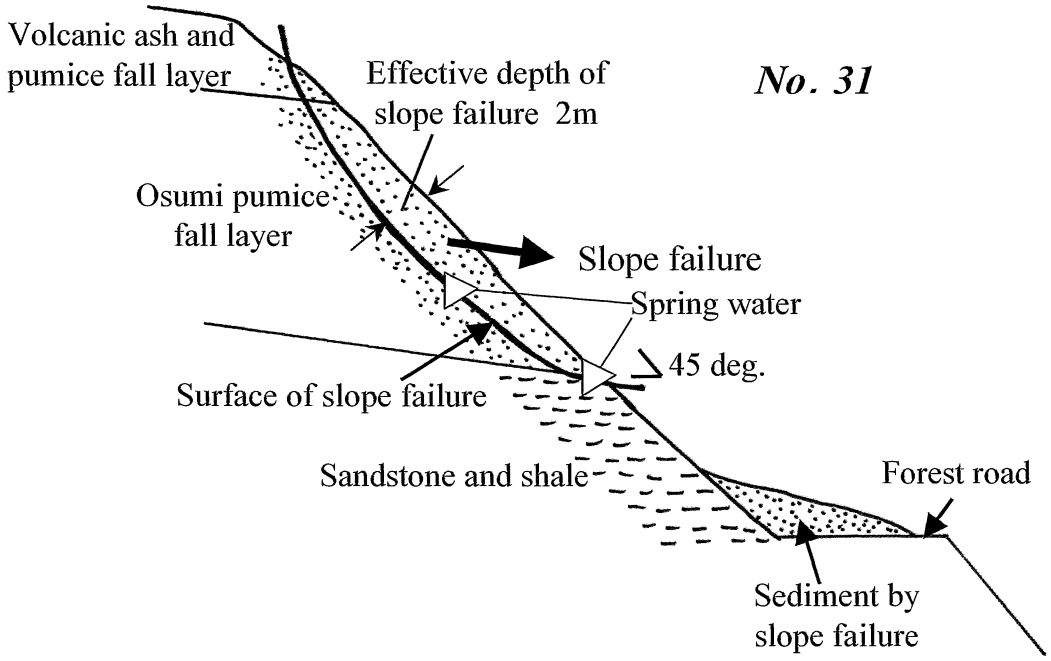


Fig. 4 Pattern diagrams and state of erosion and slope failure observed at sample point No.25.

water. The width of slope failure was 15 m, with a slope length of 15 m, and an effective depth of slope failure of 5 m. Thus, the area of slope failure was 225 m^2, and the sediment yield due to slope failure was 1,125 m^3.

The one remaining type of forest road damage, not illustrated above, is that due to the clogging of conduits and the partial failure of forest roads as a result of inundation by sediments due to debris flow, as observed at sample point No.5 in Fig. 1 (**Fig. 7**).

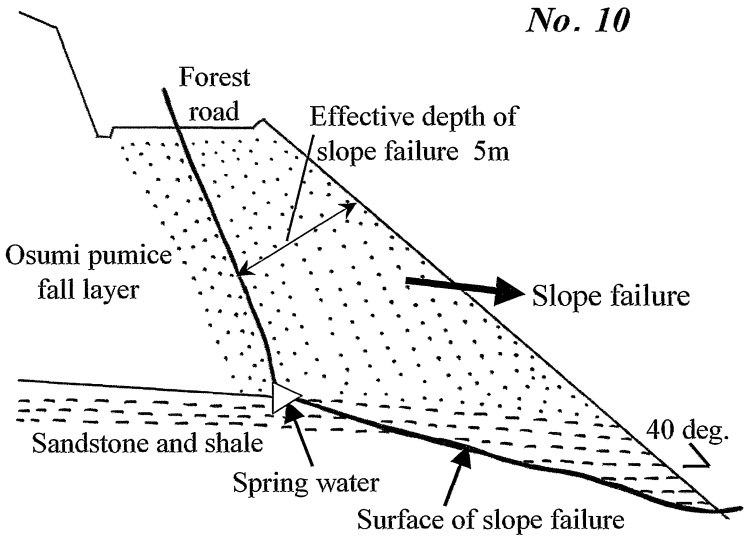
A large amount of rain water is stored in the Osumi pumice layer and, as a result, water conservation in the watershed covered by the Osumi pumice is very high (Jitousono and Shimokawa, 1990). Compared to shallow landslides, few groundwater-related slope failures have occurred on slopes bordering the forest roads in the Takakuma Experimental Forest (Ashihara et al., 2005). The chief cause of such failure in the current study was the the large-scale rainfall of typhoon Nabi on



Profile

Slope failure scar

Fig. 5 Pattern diagrams and state of erosion and slope failure observed at sample point No.31.



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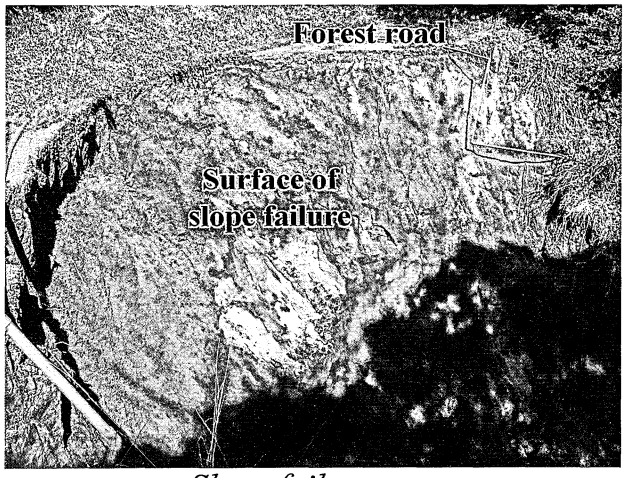
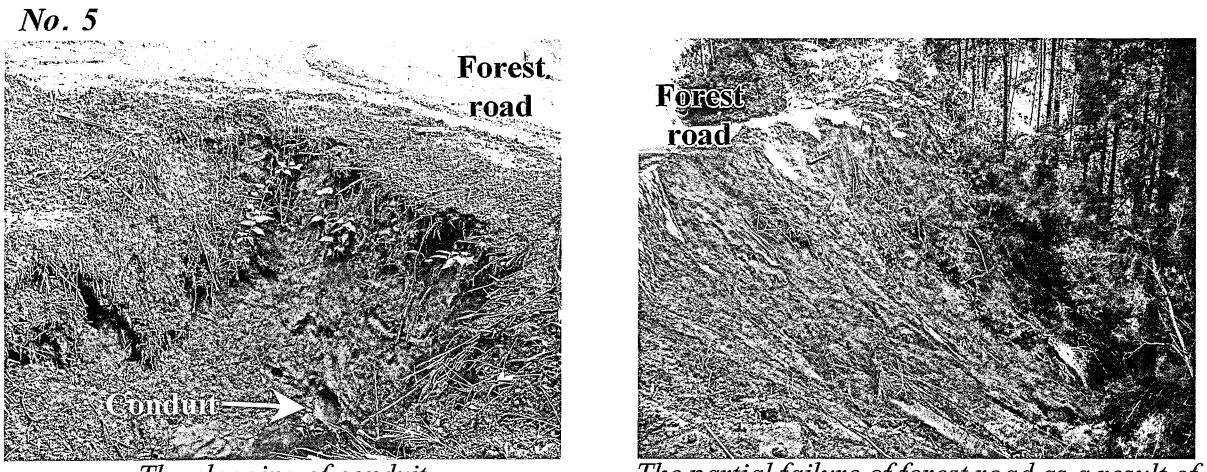


Slope failure scar

Fig. 6 Pattern diagrams and state of erosion and slope failure observed at sample point No.10.



The clogging of conduit

The partial failure of forest road as a result of inundation by sediments due to debris flow

Fig. 7 State of erosion and slope failure observed at sample point No.5.

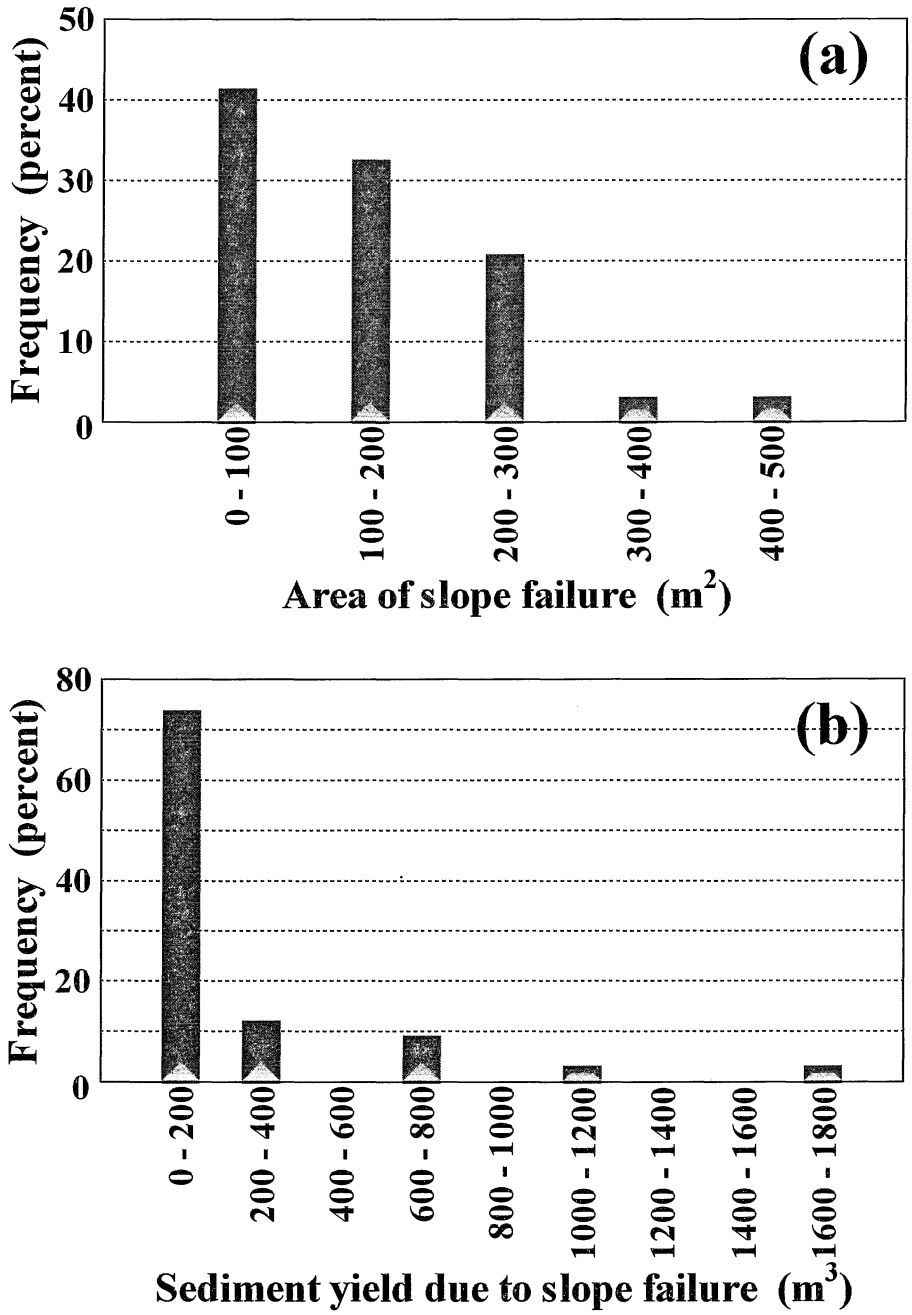


Fig. 8 Histograms showing (a) area of slope failure and (b) sediment yield due to a slope failure, within the study area.

September 2005 and the large amount of rain water stored in the Osumi pumice layer.

Fig. 8 shows histograms of (a) area of slope failure and (b) sediment yield due to slope failure, within the study area. The area of slope failure ranged from 16 m^2 to 400 m^2 (average 133 m^2). The sediment yield due to slope failure ranged from 10 m^3 to 1,600 m^3 (average 223 m^3). Seventy percent of the areas of slope failure and the total sediment yield due to slope failure within the study area were below 200 m^2 and 300 m^3, respectively. The principal types of large-scale slope failure, identified on forest roads, were slope failure occurring on the downhill sides below forest roads as a result of groundwater between the bedrock and pyroclastic fall deposits, augmented by an influx of rain water, deep-seated landslide resulting from groundwater between the bedrock and pyroclastic fall deposits combining with an influx of rain water, and failure of the subbase and subgrade bearing body of the forest road itself, as a result of groundwater between the bedrock and pyroclastic fall deposits together with an influx of rain water.

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2005年９月の台風14号による鹿児島大学附属高隈演習林の林道法面の被害状況

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要　旨

2005年９月の台風14号による鹿児島大学農学部附属高隈演習林の林道法面の被害状況を明らかにするため，高隈演習林内の35箇所の林道法面を対象として侵食・斜面崩壊に関する調査を実施した。得られた結果は以下の通りである。

(1) 調査地は砂岩・頁岩が基盤岩となり，それを姶良カルデラおよび阿多カルデラから噴出した降下火砕物や桜島火山から噴出した火山灰・軽石が被覆した地質構造となっている。調査地でみられたおもな侵食・斜面崩壊の形態として，基盤岩とその上部を覆う大隅降下軽石層の間に集中した雨水および地下水に起因して発生した林道の谷側斜面の崩壊，自然および切り取り斜面への雨水の浸透に起因した表層崩壊，基盤岩とその上部を覆う大隅降下軽石層の間に集中した雨水および地下水に起因して発生した深層崩壊，基盤岩とその上部を覆う大隅降下軽石層の間に集中した雨水および地下水に起因して発生した路体を支持する路盤の決壊，土石流による土砂氾濫に伴う林道の破壊および暗渠の閉塞が挙げられる。

(2) 調査地において，斜面崩壊の面積および斜面崩壊による生産土砂量の測定を行った。その結果，斜面崩壊の面積は16～400m^{2}の範囲（平均133m^2），斜面崩壊による生産土砂量は10～1,600m^{3}の範囲（平均223m^3）であった。林道の谷側斜面の崩壊，深層崩壊，および路体を支持する路盤の決壊は，調査地においてみられた他の侵食・斜面崩壊の形態に比べ規模が大きかった。

キーワード：2005年９月の台風14号，鹿児島大学附属高隈演習林，林道法面，被害の実態