Original Article

Erosion and slope failure on slopes bordering forest roads in Takakuma Experimental Forest, Kagoshima University, due to heavy rainfall on July 5th 2006

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Summary

This study clarified the nature of erosion and slope failure caused by the heavy rainfall on July 5th 2006 on slopes bordering forest roads in Takakuma Experimental Forest, Kagoshima University. Moreover, a comparison of the types and scale of erosion and slope failure caused by the typhoon Nabi, in September 2005, and the above heavy rainfall event was also conducted within the study area. Characteristic results were as follows:

(1) The geological composition of the study area was shown to be of sandstone and shale base overlaid with pyroclastic fall and pyroclastic flow deposits originating from eruptions of Ata Volcano and Aira Volcano and volcanic ash and volcanic pumice originating from eruptions of Sakurajima Volcano. Two types of erosion and slope failure were observed as a result of the heavy rainfall event: failure of the sub-base and sub-grade-bearing body of the forest road itself as a result of groundwater between the bedrock and pyroclastic fall deposits combined with the influx of rain water, and a shallow landslide resulting from infiltration and concentration of rain water in the surface soil on the cutting slope.

(2) Areas of slope failure and sediment yield due to slope failure within the study area were also investigated. The area of slope failure ranged from 5 to 80 m^2 (average: 31 m^2) and the sediment yield due to slope failure from 5 to 336 m^3 (average: 49 m^3). A larger area was affected and more sediment yield occurred with failure of the sub-base and sub-grade-bearing body compared with the shallow landslide.

(3) A greater number of slopes were damaged and more types of erosion and slope failure resulted from typhoon Nabi compared to the heavy rainfall event. Moreover, when erosion and slope failure were of the same type , the scale, especially the sediment yield due to slope failure caused by typhoon Nabi was much larger than with the heavy rainfall.

Key Words: Takakuma Experimental Forest of Kagoshima University, heavy rainfall on July 5th 2006, slopes bordering forest roads, nature of erosion and slope failure

1. Introduction

Slope failure and debris flow following heavy rainfall caused by a seasonal rain front occurred on Osumi peninsula in Kagoshima Prefecture on July 5th 2006, with a daily rainfall of 253 mm and maximum hourly rate of 88 mm (Takatoge automated meteorological data acquisition system, 2006). Considerable damage was caused to houses, engineering works and agriculture and forestry in the area (Erosion and Sediment Control Department, Ministry of Land, Infrastructure and Transport, 2006), and furthermore, an evacuation recommendation was issued for all residents of Tarumizu City.

The heavy rainfall event also caused considerable damage to the slopes bordering forest roads in Takakuma Experimental Forest of Kagoshima University, making some of the roads completely impassable. Damage to forest roads occurred previously in Takakuma Experimental Forest in 1997, 2004 and 2005 (Ashihara et al., 2005; Teramoto et al., 2006).

We carried out a field investigation of the slopes bordering these forest roads in order to clarify the nature of the erosion and slope failure caused by the heavy rainfall event on July 5th 2006. Moreover, a comparison of the types and scale of erosion and slope failure caused by typhoon Nabi in September 2005 (Teramoto et al., 2006) and the heavy rainfall in July 2006 was conducted. The results of this investigation are presented below.

2. Rainfall conditions

Fig. 1 shows the changes in hourly rainfall from July 5th to 6th 2006 recorded using an automated meteorological data acquisition system (Takatoge automated meteorological data acquisition system, 2006). It began to rain on July 5th at 11 am, reaching an hourly maximum of 88 mm between 21 and 22 o'clock. This hourly rate was also the maximum value recorded by the acquisition system since 1976. Total rainfall from July 5th to 6th was 290 mm, and the heavy rainfall continued for a comparatively short time.

3. Study area and methods

The study area encompassed slopes both above and below Kisyukusya forest road, Takahana forest road, Hiyamizudani forest road, Nagatani forest road and Takeno forest road within Takakuma Experimental Forest, situated east of Sakurajima Volcano (**Fig. 2**). Ten sample slopes bordering the forest roads and damaged by the heavy rainfall event on July 5th 2006 were investigated (Fig. 2). To clarify the nature of erosion and slope failure we investigated the following: type of slope failure; geological and geomorphological features; the presence of spring water; the shape and inclination of the slopes; vegetation coverage; the area of slope failure; and sediment yield due to slope failure. Sediment yield was calculated from the area and effective depth of slope failure measured in the field investigation. The nature of erosion and slope failure caused by typhoon Nabi on September 2005 was also investigated within the study area (Teramoto et al., 2006).

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

4. Types of erosion and slope failure

Fig. 3 shows the type of erosion and slope failure observed at sample point No.1 in Fig. 2. Here, failure of the sub-base and sub-grade-bearing body of the forest road itself occurred as a result of groundwater between the bedrock (sandstone and shale) and pyroclastic fall deposits (Osumi pumice fall layer) augmented by the influx of rain water. The width of slope failure was 6 m with a slope length of 7 m and an effective depth of slope failure of 8 m; accordingly, the area of slope failure was 42 m^2 and the sediment yield due to slope failure was 336 m^3.

Fig. 4 shows the type of erosion and slope failure observed at sample point No.5 in Fig. 2. Here, a shallow landslide was resulted from infiltration and concentration of rain water in the surface soil on the cutting slope. The width of slope failure was 4 m with a slope length of 10 m and an effective depth of 0.5 m; accordingly, 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 occurred on a small scale compared to the other types observed within the study area.

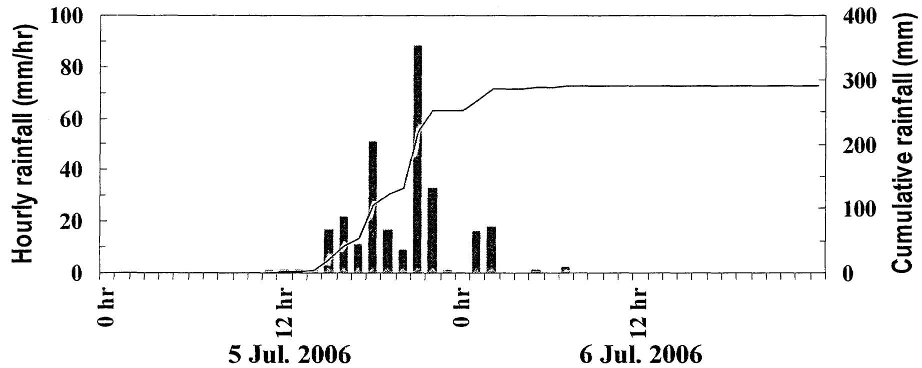

Fig. 1 Changes in hourly rainfall from July 5th to 6th 2006 recorded by an automated meteorological data acquisition system.

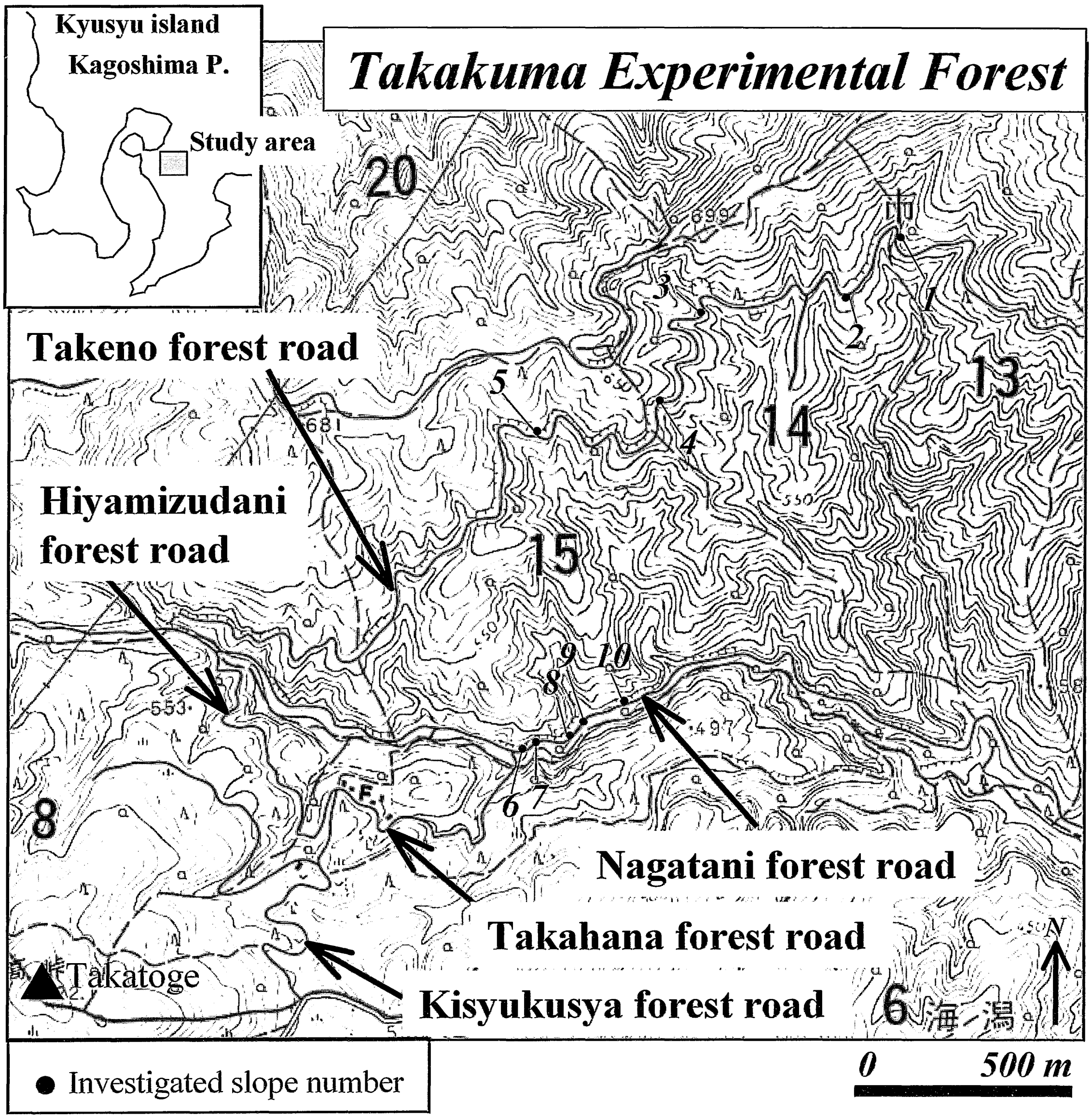

Fig. 2 Location of the study area.

The area of slope failure ranged from 5 to 80 m^2 (average 31 m^2) and the sediment yield due to slope failure from 5 to 336 m^3 (average 49 m^3). Moreover, 90% of the areas of slope failure and sediment yields due to slope failure were below 50 m^2 and 50 m^3, respectively. A larger area was affected and more sediment yield occurred as a result of failure of the sub-base and sub-grade-bearing body of the forest road compared with the shallow landslide.

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, 1992). Compared to shallow landslides, few groundwater-related slope failures have occurred on slopes bordering the forest roads in Takakuma Experimental Forest (Ashihara et al., 2005; Teramoto et al., 2006). The main cause of such failure in the current study was the heavy rainfall on July 2006 and the large amount of rain water stored in the Osumi pumice layer.

5. Comparison of the types and scale of erosion and slope failure resulting from typhoon Nabi in September 2005 and the heavy rainfall event in July 2006

Table 1 shows a comparison of the type and cause of erosion and slope failure, the area of slope failure and sediment yield due to slope failure resulting from typhoon Nabi in September

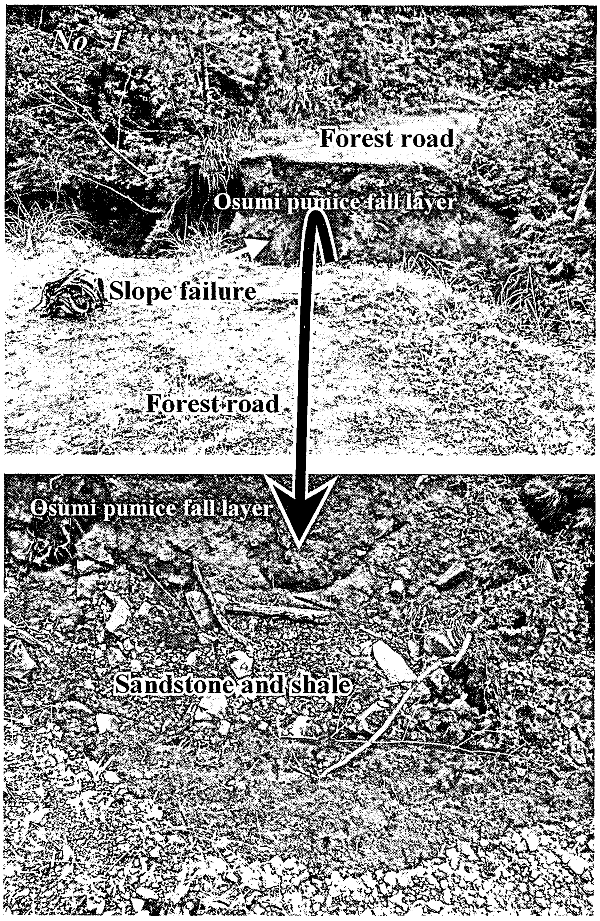

Fig. 3 Type of erosion and slope failure observed at sample point No.1 in Fig.2.

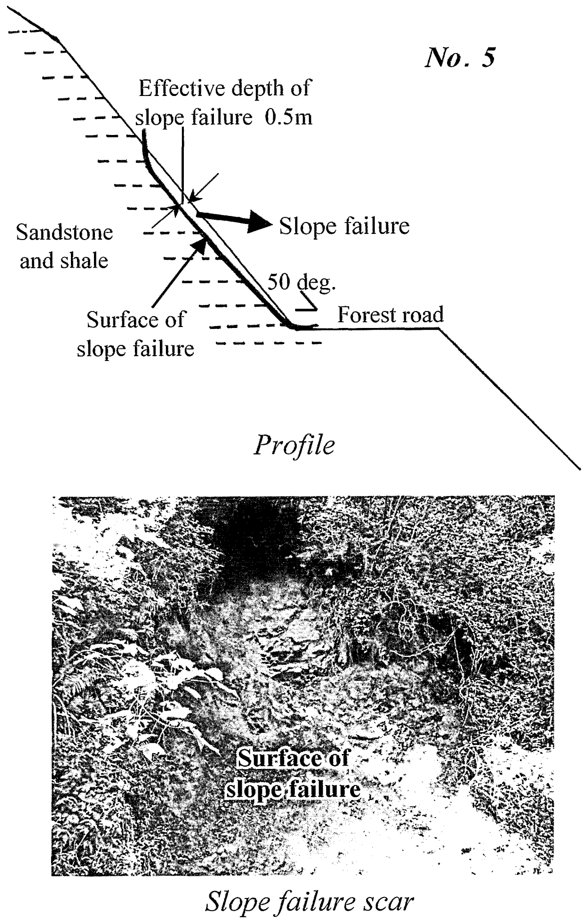

Fig. 4 Type of erosion and slope failure observed at sample point No.5 in Fig.2.

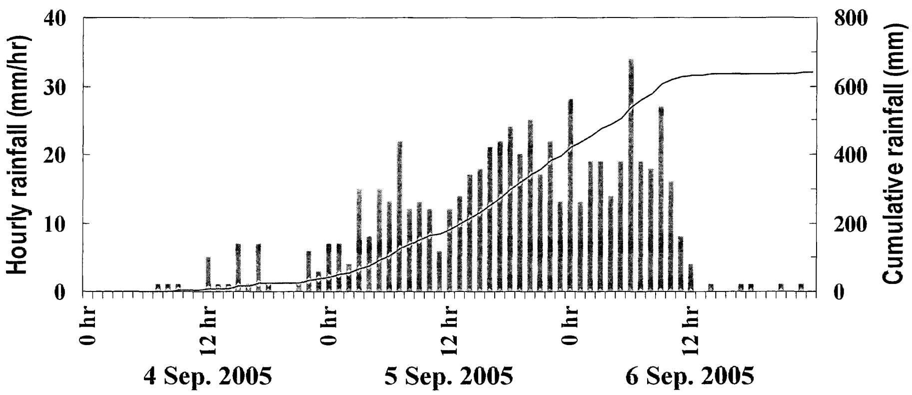

Fig. 5 Changes in hourly rainfall generated by typhoon Nabi from September 4th to 6th 2005 recorded by an automated meteorological data acquisition system.

2005 (Teramoto et al., 2006) and the heavy rainfall event in July 2006. **Fig. 5** shows the changes in hourly rainfall generated by typhoon Nabi from September 4th to 6th 2005, recorded by the Takatoge automated meteorological data acquisition system (2005). Maximum hourly rainfall was 38 mm and total rainfall was 638 mm, and comparatively heavy rainfall continued for a long time. Maximum hourly rainfall generated by typhoon Nabi was less than that caused by heavy rainfall in July 2006. However, the total rainfall generated by typhoon Nabi was much greater than that caused by the heavy rainfall event (Fig. 1).

A greater number of slopes were damaged and several types of erosion and slope failure occurred as a result of typhoon Nabi

Table 1 Comparison of the types and cause of erosion and slope failure, the area of slope failure and sediment yield due to slope failure as a result of typhoon Nabi in September 2005 and heavy rainfall in July 2006 within the study area.

Type of erosion and slope failure within the study area	**Cause of erosion and slope failure within the study area**	**Number of observed sample slope within the study area**		**Area of slope failure (m^2)**				**Sediment yield due to slope failure (m^3)**			
		Sep. 2005 (Teramoto et al., 2006)	**Jul. 2006**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**
				Sep. 2005 (Teramoto et al., 2006)		**Jul. 2006**		**Sep. 2005 (Teramoto et al., 2006)**		**Jul. 2006**	
Slope failure occurring on the downhill side of the forest road	Groundwater between the bedrock and pyroclastic fall deposits combining with an influx of rain water	18	0	210-400	295	-	-	620-1600	820	-	-
Deep-seated landslide in the natural slope		1	0	320	320	-	-	640	640	-	-
Failure of the subbase and subgrade bearing body of the forest road itself		1	1	225	225	42	42	1125	1125	336	336
Shallow landslide in the cutting slope	Infiltration and concentration of rain water into permeable surface soil in the slope	13	9	16-260	102	5-80	30	10-180	78	5-40	17
Shallow landslide in the natural slope		2	0	150-250	200	-	-	120-250	185	-	-

compared to the heavy rainfall event. Moreover, when erosion and slope failure were of the same type, the scale, especially the sediment yield due to slope failure was much larger with typhoon Nabi compared to the heavy rainfall event. The different types of erosion and slope failure resulting from groundwater between the bedrock (sandstone and shale) and pyroclastic fall deposits (Osumi pumice fall layer) combined with the influx of rain water caused by typhoon Nabi in September 2005 was especially notable compared to those caused by the heavy rainfall event in July 2006.

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2006年7月5日の豪雨に伴う鹿児島大学附属高隈演習林の林道法面における侵食・斜面崩壊

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要　旨

2006年7月5日の豪雨に伴う鹿児島大学農学部附属高隈演習林の林道法面における侵食・斜面崩壊の実態を調査した。さらに，高隈演習林内の同じ地域を対象として調査した，2005年9月の台風14号と2006年7月の豪雨に伴う林道法面の侵食・斜面崩壊の形態および規模についても比較した。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，それを阿多カルデラおよび姶良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路体を支持する路盤の決壊，ならびに切り取り斜面への雨水の浸透に起因した表層崩壊の2つが挙げられる。

(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5～80m²の範囲（平均31m²），斜面崩壊による生産土砂量は5～336m³の範囲（平均49m³）であった。路体を支持する路盤の決壊は，切り取り斜面における表層崩壊に比べ大きな規模を示した。

(3) 同じ調査地で比較すると，2005年9月の台風14号に伴う林道法面の被害箇所数および林道法面における侵食・斜面崩壊の形態の数は，2006年7月の豪雨に伴うそれらよりはるかに多かった。さらに，同じ形態の侵食・斜面崩壊で比較すると，2005年9月の台風14号に伴う林道法面における侵食・斜面崩壊の規模，特に斜面崩壊による生産土砂量は，2006年7月の豪雨に伴うそれに比べはるかに大きかった。

キーワード：鹿児島大学附属高隈演習林，2006年7月5日の豪雨，林道法面，侵食・斜面崩壊の実態