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# Conditions of driftwood caused by typhoon Nabi in September, 2005 in the Kawasaki river basin of Tarumizu, Kagoshima

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**Abstract:** A total rainfall of 600 mm or more fell from September 4th to 6th, 2005 during typhoon Nabi, resulting in many slope failures and debris flows in Kagoshima prefecture on the Osumi peninsula. This sediment-related disaster killed five people and caused considerable damage. In this paper, to clarify the conditions of slope failures, we conducted a field investigation of the volume of trees felled by slope failures and the movement of the driftwood carried by debris flows due to typhoon Nabi in the Kawasaki river basin of the city of Tarumizu in Kagoshima prefecture. Five slope failures in the basin at an altitude below 250 m were identified as being due to typhoon Nabi. All were shallow landslides. Slope failures occurred on steep slopes consisting of a sedimentary rock base covered with volcanic ash and pumice. The area of slope failure ranged from 150 $m^2$ to 4800 $m^2$. Of the 379.4 $m^3$ total volume of trees felled by slope failures, 288.1 $m^3$ was conifer and 91.3 $m^3$ was broadleaf trees. The driftwood budget shows that of the 379.4 $m^3$ total driftwood, 219.8 $m^3$ was caught by check dams, 128.0 $m^3$ was caught in the channel and 31.6 $m^3$ was caught in the slope failure scars.

## 1 Introduction

A sediment-related disaster occurred following typhoon Nabi over wide areas of Kyushu, Chugoku and Shikoku from September 6th to 7th, 2005. Rainfall due to typhoon Nabi from September 4th to 6th, 2005 was recorded by an automated meteorological data acquisition system in Takatoge, Tarumizu, on the Osumi peninsula in Kagoshima prefecture. The maximum hourly rainfall was 38 mm and the total rainfall was 600 mm or more. Heavy rainfall due to typhoon Nabi continued for a relatively long time (Takatoge automated meteorological data acquisition system, 2005). As a result, many slope failures and debris flows were generated in Tarumizu, killing five people and causing considerable damage to houses, engineering works and the agricultural, forest and fishing industries. In addition, large sediment flow completely stopped traffic on the national road passing through Tarumizu and a village was temporarily isolated (Taniguchi *et al*., 2005; Teramoto *et al*., 2006).

There have been frequent sediment-related disasters due to slope failures and debris flows in Tarumizu; for example, those accompanying the heavy rainfall of typhoon No. 11 in July 1989 and heavy rainfall in 1992 and 1993 (Jitousono and Shimokawa, 1995).

In the present study, we conduct a field investigation in the Kawasaki river basin of Tarumizu to clarify the conditions of slope failures and determine the volume of trees felled by slope failures and the movement of driftwood due to debris flows resulting from typhoon Nabi.

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## 2 Study area and methods

The study area was the Kawasaki river basin on the north side of Tarumizu (Figure 1). The basin has an area of 6.4 $km^2$ and an altitude from 0 m to 704 m above sea level. The drainage density of the basin was calculated using a topographical 1/25000 map drawn up by the Geographical Survey Institute (Kagoshima prefecture, 2004). The drainage system was divided using Strahler's method. The drainage density of the basin was 9.3 $km/km^2$.

The slope inclination of the basin was calculated using a numeric map with a 50 m mesh drawn up by the Geographical Survey Institute (Kagoshima prefecture, 2004). The basin was divided into areas of slope inclinations in 10 degree intervals using the slope inclination distribution chart. 11.7% of the total area had an inclination less than 10 degrees, 18.8% had an inclination from 10 to 20 degrees, 33.4% had an inclination from 20 to 30 degrees, 32.5 % had an inclination from 30 to 40 degrees, and 3.6% had an inclination greater than 40 degrees. The average inclination of the basin was 24.3 degrees.

The geology of the study area consists of a sedimentary rock base covered with pyroclastic fall and flow deposits from the Aira and Ata volcanoes and volcanic ash and pumice from successive eruptions of Sakurajima volcano.

Since no aerial photograph was taken after typhoon Nabi, a distribution chart of the slope failure scars was made from a field investigation. Furthermore, the area of each slope failure was calculated from a distribution chart of slope failure scars caused by typhoon Nabi.

A field investigation of the volume of trees felled in

slope failures, the movement of driftwood carried by debris flows generated by typhoon Nabi, and the volume of driftwood caught in the channel and check dams was carried out for the Kawasaki river basin. To estimate the volume of trees that fell owing to slope failures, we assumed the constituent tree species and structure of vegetation on slopes before the occurrence of slope failures were the same as for vegetation in four survey areas on slopes adjacent to the slope failure scars (Figure 1). A square area was 10 m long and 10 m wide. The species, height, and diameter at breast height of the trees not less than 3 m tall were surveyed in each square. The volume of the trees per square area of 100 $m^2$ was calculated from the species, height, and diameter at breast height of the trees using a volume-of-tree conversion table (Forestry Agency, 1970). These data were converted into the volume of trees for the area of each slope failure. Moreover, to estimate the volume of driftwood caught in the channel and check dams, we surveyed the species (conifer or broadleaf), height, and average diameter of the driftwood. The volume of the driftwood was estimated by multiplying the height of a tree by the average diameter of the tree. Field investigation was carried out for altitudes below 250 m, at which there were many slope failures and a large amount of the driftwood produced (Figure 1).

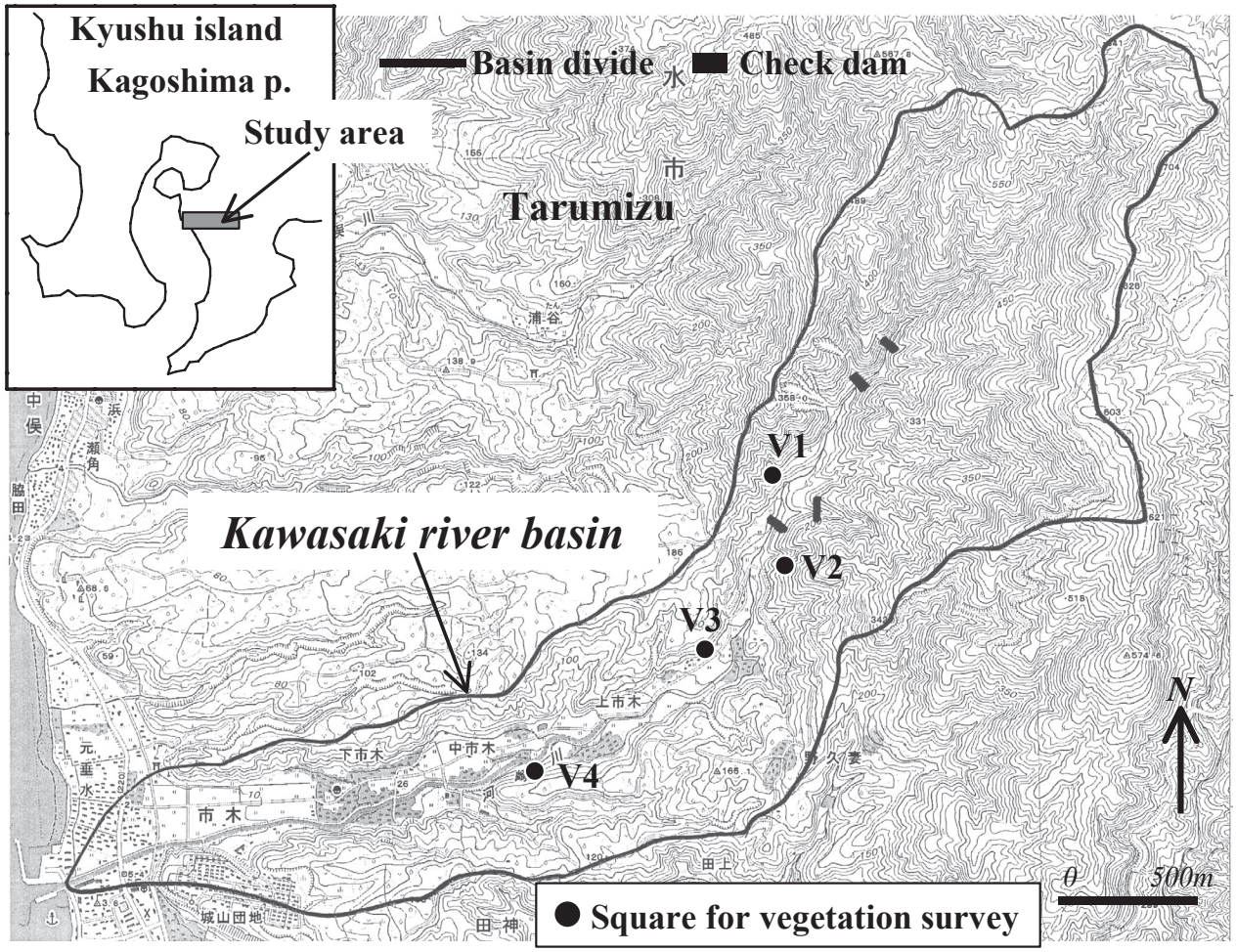


Figure 1: Location of the study area

### 3 Generation of slope failures and the volume of felled trees

Figure 2 is a distribution chart of the slope failure scars caused by typhoon Nabi in the Kawasaki river basin. The number of slope failures was confirmed by the field investigation to be five. All were shallow landslides. Slope failures were generated on steep slopes consisting of a sedimentary rock base covered with volcanic ash and pumice resulting from successive eruptions of Sakurajima. The area of slope failure ranged from 150 $m^2$ to 4800 $m^2$ (Table 1). The maximum hourly rainfall from September 4$^{th}$ to 6$^{th}$, 2005 due to typhoon Nabi was 38 mm and the total rainfall was about 630 mm (Takatoge automated meteorological data acquisition

system, 2005).

Table 2 gives the constituent tree species and number of trees in the four vegetation survey squares. Tree species for a tree height of not less than 3 m comprised *Cryptomeria japonica* as a conifer and *Cyclobalanopsis glauca, Quercus salicina and Quercus cuspidata var. sieboldii* as broadleaf trees mainly in the V1 and V2 squares and only *Cryptomeria japonica* as a conifer in the V3 and V4 squares.

Table 3 gives the volume of trees converted into the volume of the trees per the area of each slope failure generated by typhoon Nabi. In addition, the volumes of trees are divided into volumes for conifer and broadleaf trees. The volume of trees that fell in the slope failure in S1 was greater than volumes in the other survey squares. Of the 379.4 $m^3$ total volume of trees, 288.1 $m^3$ (75.9%) was conifer and 91.3 $m^3$ (24.1%) was broadleaf trees.

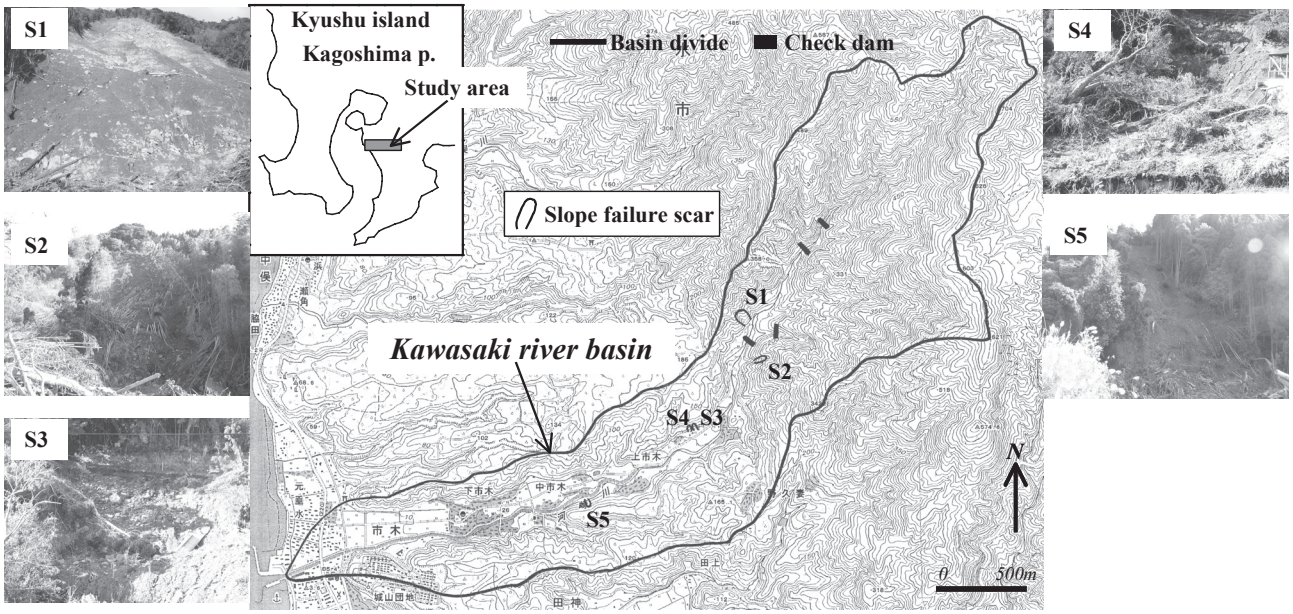


Figure 2: Distribution chart of the slope failure scars caused by typhoon Nabi in the Kawasaki river basin

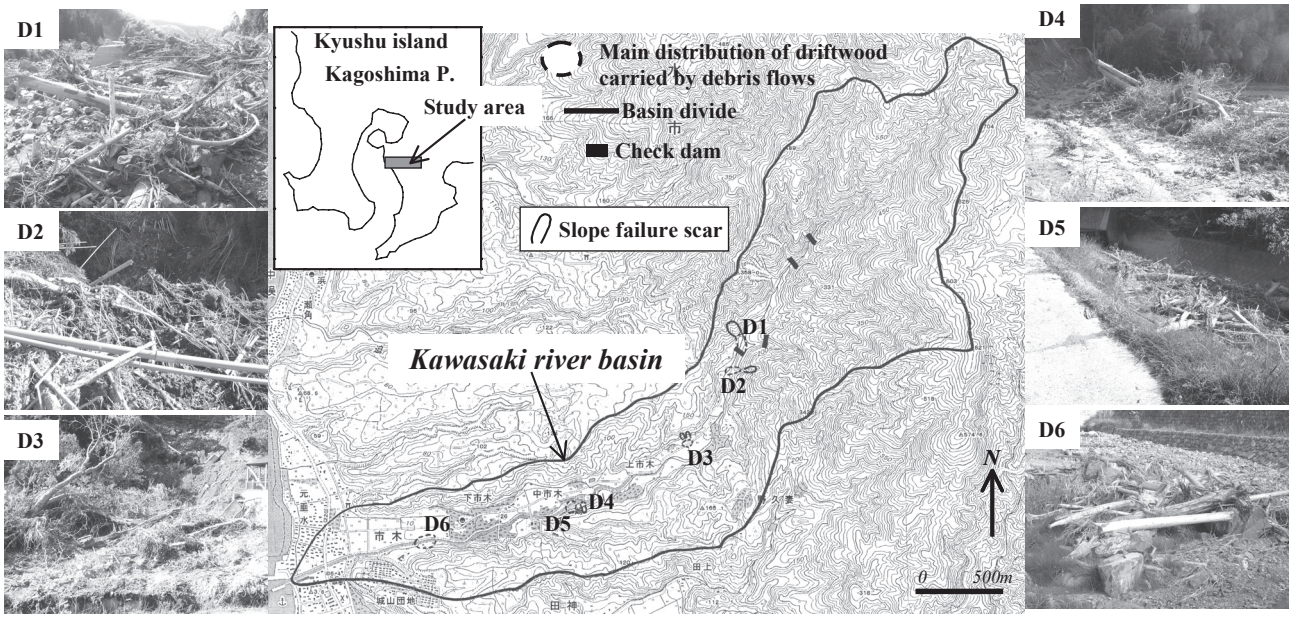


Figure 3: Main distribution chart of the driftwood carried by debris flows in the Kawasaki river basin

Table 1: Areas of slope failures in the Kawasaki river basin

| Number in Figure 2 | Average slope (degree) | Area of slope failure ($m^2$) |
|---|---|---|
| S1 | 45 | 4,800 |
| S2 | 40 | 1,200 |
| S3 | 45 | 150 |
| S4 | 45 | 300 |
| S5 | 40 | 300 |

Table 2: Constituent tree species and number of trees in the four vegetation survey squares

| Number in Figure 1 | V1 | V2 | V3 | V4 |
|---|---|---|---|---|
| Slope (degree) | 42 | 45 | 40 | 40 |
| Square area ($m^2$) | 100 | | | |
| Species of tree | Number of tree | | | |
| *Cryptomeria japonica* | 6 | 8 | 15 | 8 |
| *Quercus salicina* | 4 | | | |
| *Quercus glauca* | 9 | 8 | | |
| *Castanopsis cuspidata var. sieboldii* | | 3 | | |
| *Camellia japonica* | 2 | 4 | | |

Table 3: Volume of the trees felled in slope failures in the Kawasaki river basin

| Number in Figure 2 | Total volume of trees ($m^3$) | | |
|---|---|---|---|
| | Conifer | Broadleaf tree | Total |
| S1 | 171.9 | 60.4 | 232.3 |
| S2 | 71.5 | 30.9 | 102.4 |
| S3 | 9.0 | 0 | 9.0 |
| S4 | 18.0 | 0 | 18.0 |
| S5 | 17.7 | 0 | 17.7 |
| Total | 288.1 | 91.3 | 379.4 |

## 4 Movement of driftwood carried by debris flows

Figure 3 shows the main distribution of driftwood carried by debris flows in the Kawasaki river basin. Moreover, the figure shows the distribution of slope failure scars caused by typhoon Nabi. Vegetation that covered slopes in the basin was felled by the slope failures. The felled trees were carried downstream by debris flows and caused much damage in the basin. Driftwood was caught by check dams and in the channel.

Table 4 gives the total volume of driftwood carried by debris flows in the Kawasaki river basin. Driftwood came not only from slopes covered with conifers but also slopes covered with broadleaf trees. The driftwood budget shows that 219.8 $m^3$ (58.0%) of the 379.4 $m^3$ total driftwood was caught by the check dams, 128.0 $m^3$ (33.7%) was caught in the channel and 31.6 $m^3$ (8.3%) was caught in the slope failure scars.

Table 4: Total volume of driftwood carried by debris flows in the Kawasaki river basin

| | Total volume of driftwood ($m^3$) | | |
|---|---|---|---|
| | Conifer | Broadleaf tree | Total |
| Driftwood caught by the check dams | 185.7 | 34.1 | 219.8 |
| Driftwood caught in the channel | 82.1 | 45.9 | 128.0 |
| Driftwood caught in the slope failure scars | 20.3 | 11.3 | 31.6 |
| Total | 288.1 | 91.3 | 379.4 |

## 5 Conclusions

To clarify the conditions of slope failures, we conducted a field investigation of the volume of trees felled due to slope failures and the movement of these trees and driftwood as they were carried by debris flows in the Kawasaki river basin of Tarumizu, Kagoshima, as a result of typhoon Nabi in September 2005. The results are as follows:

(1) Five slope failures in the Kawasaki river basin at altitudes below 250 m were identified as being due to typhoon Nabi. All were shallow landslides. Slope failures generated on steep slopes consisting of a sedimentary rock base covered with volcanic ash and pumice resulting from successive eruptions of Sakurajima. The area of slope failure ranged from 150 $m^2$ to 4800 $m^2$.

(2) Of the 379.4 $m^3$ total volume of trees felled in slope failures, 288.1 $m^3$ was conifer and 91.3 $m^3$ was broadleaf trees. Driftwood came not only from slopes covered with conifer but also slopes covered with broadleaf trees. The driftwood budget shows that of the 379.4 $m^3$ total volume of driftwood, 219.8 $m^3$ was caught by check dams, 128.0 $m^3$ was caught in the channel and 31.6 $m^3$ was caught in the slope failure scars.

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