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Impact of revegetation on infiltration capacity and surface roughness on hill slopes of Mt. Unzen

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Abstract: Between 1991 and 1995, the Mt. Unzen volcano erupted with numerous pyroclastic flows; the flow deposits thickly covered wide areas of the volcano's hillside slopes and radically altered the hydrologic and erosion regimes of the area. As a result, debris flows have frequently occurred in the hillside rivers of Unzen-Fugendake. The frequency and the magnitude of debris flow occurrences decreased after 1994 because of the recovery of infiltration capacity, due to erosion of fine surface tephra. Vegetation recovery was caused by active revegetation works using helicopters. We investigated the impact of recovering vegetation on infiltration capacity and surface roughness based on a field study. Revegetation on devastated hillside slopes increased infiltration capacity and surface roughness, and both infiltration capacity and surface roughness increases were considered to contribute to a decrease in overland flow.

1 Introduction

Mt. Unzen is a 1486 m composite stratovolcano located in northwest of Shimabara peninsula, Kyushu island (Figure 1). Unzen's recent activity commenced with an eruption on the 17th of November 1990. This was followed by series of pyroclastic flows between March 1991 and March 1995, due to periodic collapse of summit lava domes, which killed a total of 44 people. The flows were deposited widely and thickly over hill slopes and river basins, creating a radical change in local slope hydrology and erosion. Alteration of slope hydrology was followed by severe erosion, with high sediment yield and discharge from slopes and river basins (Kobashi *et al.*, 1994; Nishida *et al.*, 1998; Yamakoshi and Suwa, 1998, 2000; Teramoto *et al.*, 2004). Much sediment flowed to the coast via debris flows, causing considerable damage to coast and coastal forest around Unzen-Fugendake.

The studies of Nishida *et al.* (1998), Yamakoshi and Suwa (1998, 2000) and Teramoto *et al.* (2004) demonstrated a decrease in sediment discharge from volcanic areas due to revegetation. To implement erosion control on Unzen-Fugendake, revegetation works using helicopters have been conducted since 1993. The purpose of this study is to characterize the impact of vegetation recovery on soil infiltration capacity and surface roughness on Unzen-Fugendake's slopes. Due to debris flow discharge being influenced by infiltration capacity and surface roughness, their characterization will aid the conservation of Unzen-Fugendake's coastal ecosystems.

2 Study area and methods

The study area is part of the Mizunashi river basin located on the eastern slopes of Unzen-Fugendake (Figure 1). The area is covered widely and thickly with pyroclastic flow deposits resulting from successive eruptions of Unzen (Photo 1). To implement erosion control and revegetation on hill slopes devastated by volcanic activity, revegetation works using helicopters were conducted from 1993 to 2008. As a result, the affected slopes were covered chiefly by herbs (Photo 2).

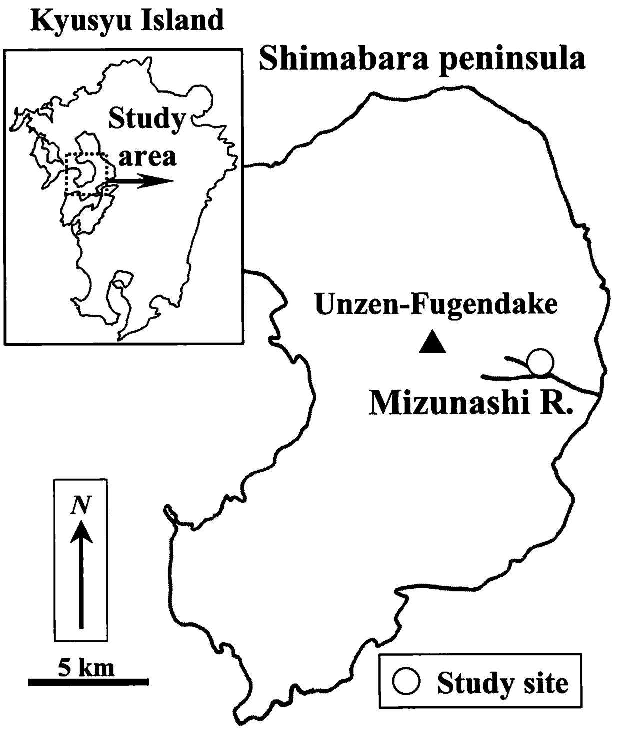

Figure 1: Location of the study area

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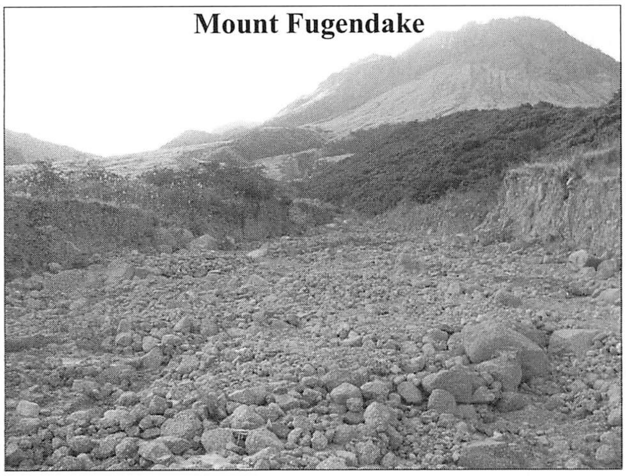

Photo 1: Hill slope covered with pyroclastic flow deposits of Unzen-Fugendake

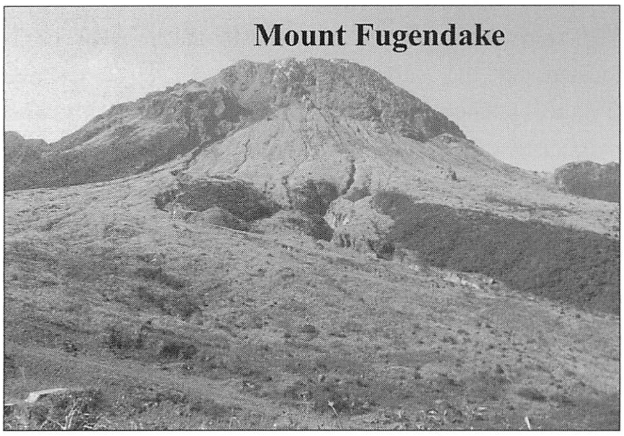

Photo 2: Revegetated hill slope of Unzen-Fugendake

To investigate the impact of revegetation on infiltration capacity and surface roughness, these were measured in areas of different plant densities (Figure 1).

Infiltration capacity was measured by the following method (Jitousono *et al*., 1996):

(1) Ten quadrats were installed on both revegetated and bare slopes. Each quadrat was 1 m × 0.5 m and sloped ~20°. Two liters of water was sprinkled within the quadrat using a watering can, which equates to a rainfall of 200 mm per hour. The volume of the water caused by overland flow was measured at the lowest part of the quadrat.

(2) The volume of infiltrated water into a quadrat was calculated by subtracting the volume of overland flow from the volume of applied water.

(3) Infiltration capacity was calculated by dividing the volume of infiltrated water by the time from commencement of water application to the end of overland flow.

Surface roughness was measured by the following method (Kitahara *et al*., 1987):

(1) Based on the infiltration measurements, the average volume of water sprinkled in the uppermost part of a quadrat and the volume of the water caused by overland flow in the lowest part of a square was calculated.

(2) The flow velocity was calculated by the time of passage of flowing water from the uppermost part to the lowest part of a quadrat.

(3) Surface roughness was calculated by using Manning's formula based on the average flow velocity and the average volume of water from the uppermost part to the lowest part of a quadrat.

After measurements of infiltration capacity and surface roughness, the above-ground plant parts and rhizomes within the quadrat were collected, and their air-dried weight determined.

To clarify the dry bulk density of the surface layer in the quadrats, undisturbed samples were collected with metallic cylinders 55 mm in diameter and 60 mm in height at three points within each quadrat. Their average value was taken as the dry bulk density of the surface layer.

3 Results and discussion

Figure 2 shows the relationship between above-ground dry plant weight and infiltration capacity. The infiltration capacity increased with dry plant weight, which is thought to result from increase in soil porosity caused by rhizome growth and interception of foliage and plant residues.

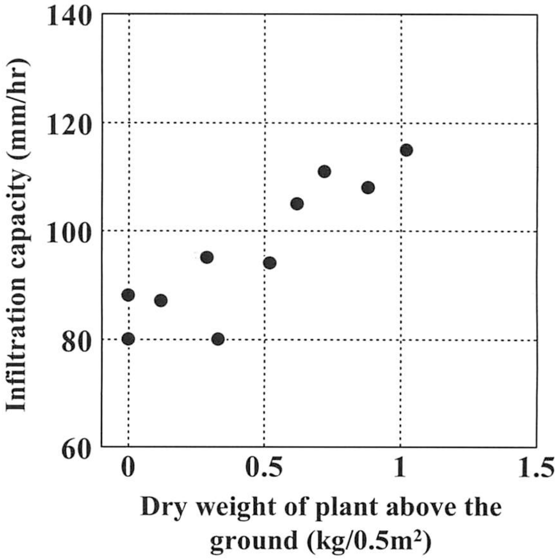

Figure 2: Relationship between above-ground dry plant weight and infiltration capacity

Figure 3 shows the relationship between dry plant weight and surface dry bulk density. Surface dry bulk density in bare quadrats was ~1.3 g cm^{-3}. Bulk density decreased with increased dry plant weight, and was ~0.8 g cm^{-3} for dry plant weight of about ~1.0 kg 0.5m^{-2}. The increase in surface bulk density is attributable to increased rhizome caused by the above-ground plant growth (Figure 4). These results are similar to those of Teramoto *et al.* (2004), who showed that surface dry bulk density was 0.6 g cm^{-3} for a dry plant weight of 1.0 kg m^{-2} on the revegetated hill slopes of Mount Sakurajima.

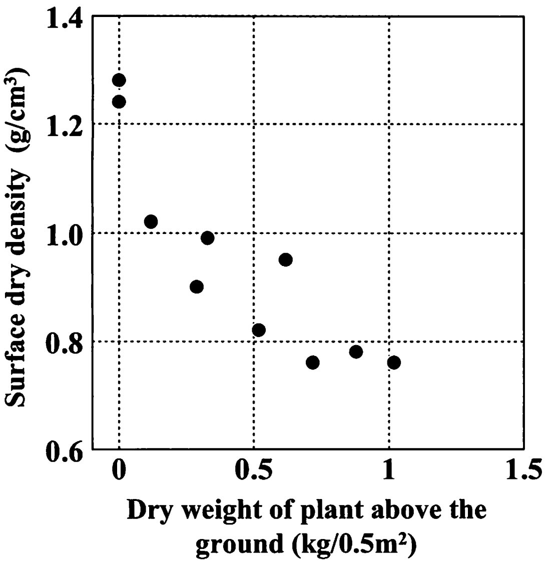

Figure 3: Relationship between above-ground dry plant weight and surface dry bulk density

Figure 5 shows the relationship between dry weight of above-ground plant matter and Manning's coefficient of roughness. Similar to the relationship between dry plant weight and infiltration capacity (Figure 2), Manning's coefficient of roughness became greater with increased dry plant weight. The increase in Manning's coefficient of roughness results from an increase in resistance force against overland flow (Teramoto *et al.*, 2004). Other studies on Unzen-Fugendake (Yamakoshi and Suwa, 2000) and Mount Sakurajima (Teramoto *et al.*, 2004) have demonstrated the relationship between dry plant weight and Manning's coefficient of roughness on revegetated hill slopes. Manning's coefficient of roughness was 0.05 sec m$^{-1/3}$ for a dry plant weight of 0.04 kg m^{-2} on Unzen-Fugendake (Yamakoshi and Suwa, 2000), and was 0.3 sec m$^{-1/3}$ for a dry plant weight of 1.0 kg m^{-2} on Mount Sakurajima (Teramoto *et al.*, 2004). These results are similar to the results of this study.

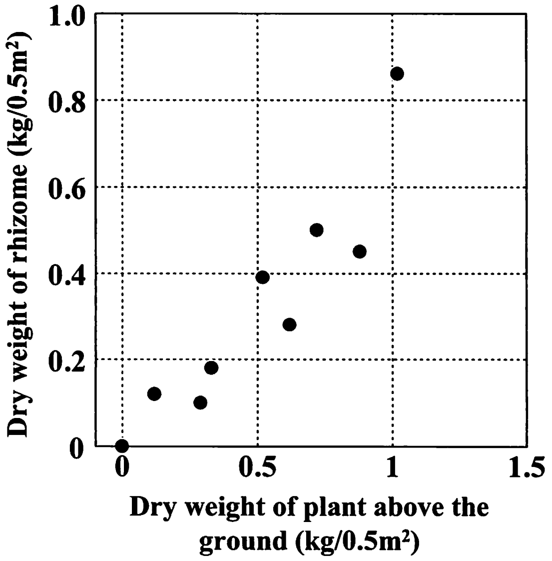

Figure 4: Relationship between above-ground dry plant weight and rhizome dry weight

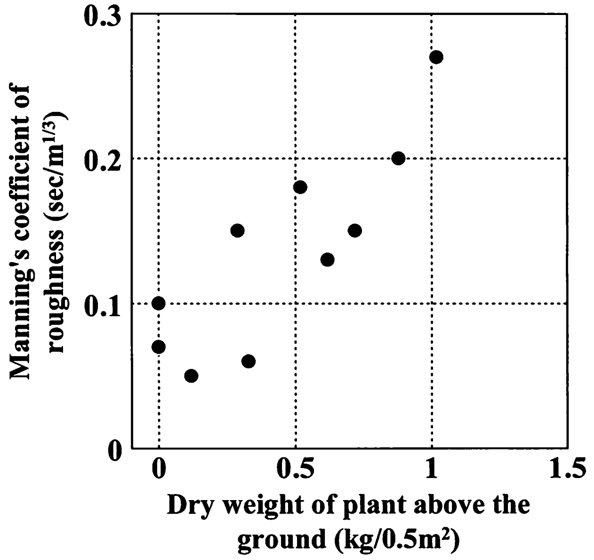

Figure 5: Relationship between above-ground dry plant weight and Manning's roughness coefficient

As described above, revegetation on devastated hill slopes brought about increases in infiltration capacity and surface roughness. The increases in infiltration capacity and surface roughness decreased the area contributing to overland flow, and they were considered to contribute to a decrease in sediment yield and discharge.

4 Conclusions

Infiltration capacity and surface roughness on the revegetated hill slopes of Unzen-Fugendake were larger than on the devastated bare slopes. The results suggested that the revegetation on the devastated hillside slopes brought about decreases in area contributing to the occurrence of overland flow, and sediment yield and discharge.

Acknowledgments

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