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Temporal changes in vegetation and soil environment caused by volcanic activity of Mount Sakurajima

Yukiyoshi Teramoto[1*] and Etsuro Shimokawa[1]

Abstract: We examined the temporal changes in vegetation and soil environment caused by volcanic activity of Mount Sakurajima via field investigations and interpreting aerial photographs taken in 1966, 1974, 1984, 1996 and 2006. The proportions of conifer and broadleaf tree areas and the timberline altitude in the study area decreased from 1966 to 1996, subsequent to volcanic activity commencing in 1972. The timberline altitude rose slowly from 1997 to 2006 because of vegetation recovery with the ebb of volcanic activity. The proportions of conifer and broadleaf tree areas decreased little after 1997. The thickness of tephra deposited since 1972, and the dry density and pH of the tephra surface layer, decreased with increasing distance from Minamidake crater.

1 Introduction

Vegetation on the hillslope and coastal area of Mount Sakurajima has declined greatly due to the impact of long-term volcanic activity since 1955. Because of the decline of vegetation, the hillslope have experienced accelerated erosion, and consequently debris and mud flows have often occurred in the rivers emanating from them (Shimokawa and Jitousono, 1987). Erosion and debris and mud flows have damaged vegetation and vegetation habitat on the hillslope and coastal areas. Moreover, because of the decline of coastal vegetation, damage from storms and salt has occurred on farms and orchards located on the lower slopes of Mount Sakurajima (Sumi and Suzuki, 1998).

The volcanic activity of Mount Sakurajima has also had a great impact on the vertical distribution of vegetation on hillslopes (Teramoto and Shimokawa, 2007). Teramoto and Shimokawa (2007) conducted a vegetation survey ranging from 500 m to 220 m above sea level (a.s.l.) on the northern flank of Mount Sakurajima. They showed that in 2007 vegetation had been severely impacted to around 220 m a.s.l., compared with 1963 when vegetation was impacted slightly by volcanic activity. Vegetation succession in 1963 was more advanced than in 2007.

The purpose of this study is to study temporal vegetation and soil environment changes caused by the volcanic activity of Mount Sakurajima. The vegetation decline caused by volcanic activity on hillslopes and in the coastal area is related closely the movement of eroded sediment transported to lower slopes via debris and mud flows. Therefore, clarifying the impact of volcanic activity on the distribution of vegetation and its habitat from hillsides to the coastal areas of Mount Sakurajima will aid the conservation of hillside and coastal ecosystems.

2 Study area and methods

The study area is located on the northern flank of Mount Sakurajima (Figure 1). The area is 2.28 km^2 with an altitude ranging from 230 m to 1117 m a.s.l.. The topography lower than 300 m a.s.l. comprises hillslopes and plateaus. Topography from 300 m to 500 m a.s.l. consists of hillslopes and steep slopes. The topography at 500 m a.s.l. and higher is steep slopes. The geology of the study area consists of a 1914 Taisho pumice layer, covered with a soil layer and tephra.

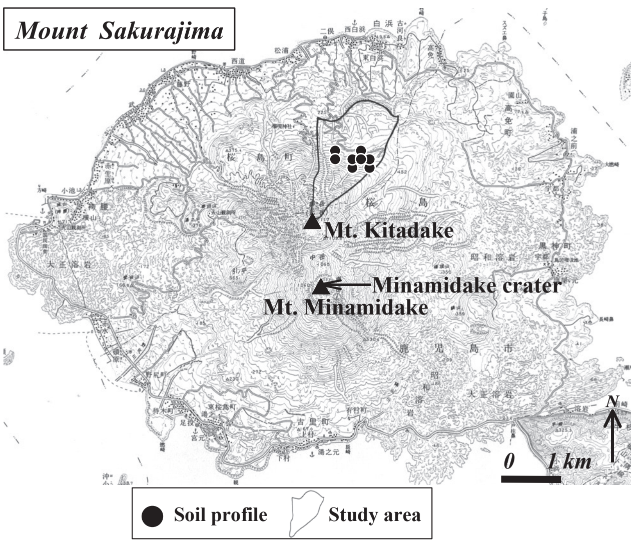

Figure 1: Location of the study area

Aerial photography was used to clarify temporal changes in vegetation and timberline caused by volcanic activity, and a distribution map of the vegetation was made. Vegetation is divided into conifer, broadleaf tree,

[1]Faculty of Agriculture, Kagoshima University, 1-21-24 korimoto, Kagoshima 890-0065, Japan

*Corresponding author: sabot @ agri.kagoshima-u.ac.jp

herb and bare areas. A distribution map of gully erosion scars was also made. Five pairs of aerial photographs taken in 1966, 1974, 1984, 1996 and 2006 were used for the analysis. The areas of conifer, broadleaf tree, herb, bare land and gully erosion scars were calculated using a distribution map produced from aerial photograph interpretation. Timberline altitude was determined using a distribution map produced by aerial photograph interpretation and a 1:25,000 topographical map produced by the Geographical Survey Institute.

Soil and tephra investigations were conducted in December 2009. Surface soil tests and pH measurements were conducted on samples collected from the tephra layer on slopes covered by broadleaf trees. The investigation of tephra distribution and deposition was conducted through observations of eight soil profiles (Figure 1). Soil profiles were sited 2.40 km to 2.95 km from the Minamidake crater of Mount Sakurajima (Figure 1), and were sited on near flat slopes where erosion processes were limited to sheet erosion. According to tephra characteristics such as color, density, hardness and humus content based on the observation of the soil profile, tephra deposition since the 1914 Taisho eruption was divided into two layers (Shimokawa and Jitousono, 1987; Teramoto *et al*., 2005). The upper tephra layer accumulated since 1972, and the lower layer accumulated from 1914 to 1971 (Shimokawa and Jitousono, 1987). The thickness of tephra deposited since 1972 was measured, and surface dry density was determined using undisturbed cores collected in 55 mm in diameter/60 mm height metal cylinders. pH measurement of the tephra surface layer was conducted as follows. An air-dried sample and pure water were packed in a container. The air-dried sample to pure water weight ratio was 1:2.5. After the container was shaken, pH was measured using a pH meter.

3 Results and discussion

3.1 Temporal changes in vegetation and timberline caused by volcanic activity

Figure 2 shows the distribution maps of conifer, broadleaf tree, herb and bare land, and gully erosion scars derived from interpretation of aerial photographs taken in 1966, 1974, 1984, 1996 and 2006. Conifer, broadleaf tree, and herb and bare land were distributed on the lower, middle and upper slopes of Mount Sakurajima, respectively. The area of broadleaf trees decreased with increase of herb vegetation and bare land. The extent of the gullies increased considerably over this time.

Figure 3(a) shows the temporal change in annual frequency of eruptions from Mount Sakurajima in the period 1955 to 2006. Mount Sakurajima has been active continuously with frequent and lively small-scale ash eruptions since 1955. The volcanic activities of the 1950s and 1960s were relatively gentle. However, since 1972, the activity has become vigorous. Mount Sakurajima erupted annually from 1974 and 1986 more than 200 times. Since 1999, the frequency of eruptions has decreased to about 20 events per year (Kagoshima local meteorological observatory, 1955-2006).

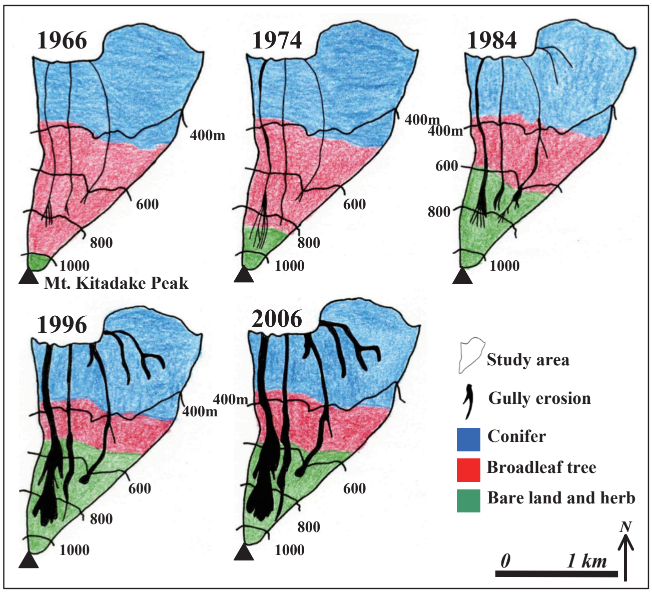

Figure 2: Distribution maps of vegetation

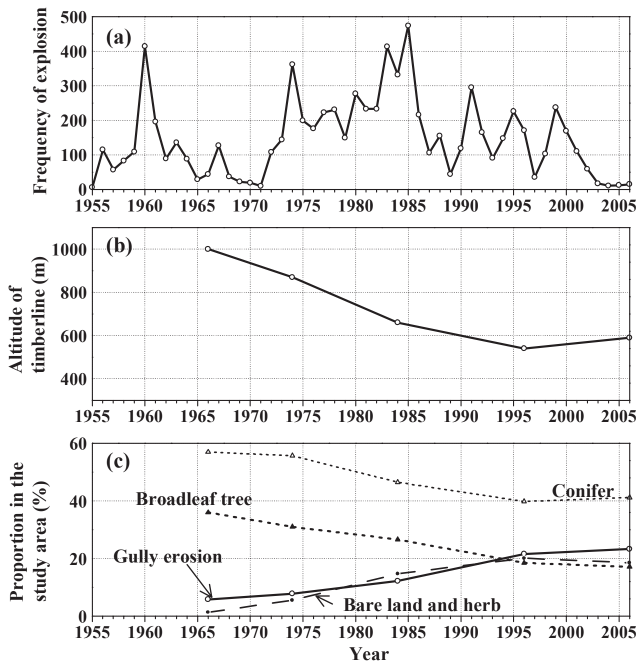

Figure 3: Temporal changes in eruptions from Mount Sakurajima (a), altitude of timberline (b), and proportion of vegetation area (c)

Figure 3(b) and Figure 3(c) show the temporal changes in timberline altitude, and the areas of conifer, broadleaf tree, herb and bare land, and gully erosion, respectively. The timberline altitude in 1966 was 1000 m, with relatively gentle volcanic activity. Since 1966 hillside vegetation has been damaged or destroyed because of tephra and gas from the Minamidake crater, and the timberline altitude has lowered. The area of gully erosion scars in has increased from 1966 to 1996 in parallel with volcanic activity, and the proportions of conifer and broadleaf tree areas decreased. From 1966 to 1996 the proportion of herb and bare land areas and gully erosion scars increased. From 1997 to 2006 vegetation on hillslopes was restored and the altitude of timberline rose slowly due to a decrease in tephra and gas resulting from an ebb in volcanic activity. After 1997, decrease in the areas of conifer and broadleaf trees, and increase in herb and bare areas and gully erosion scars were negligible.

3.2 Temporal changes in vegetation soil habitat caused by volcanic activity

Figure 4 shows the thickness of tephra deposition since 1972 based on distance from the Minamidake crater. Tephra thickness decreased with increasing distance from the Minamidake crater. Tephra thickness was between 65.5 cm and 110 cm over the distance 2.40 km to 2.95 km from the eruptive crater, with a regression analysis result (distance vs. thickness) of 0.61 (significance level of 1 %).

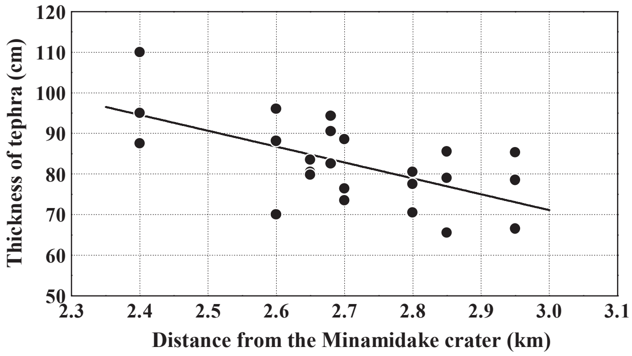

Figure 4: Thickness of tephra since 1972 according to distance from Minamidake crater

Figure 5 shows the tephra surface layer dry density since 1972 according to distance from Minamidake crater. Dry density decreased with increasing distance from Minamidake crater, reflecting an increase in void ratio with increased distance. This is thought to be due to root growth by recovering vegetation following the decrease in volcanic activity (Teramoto and Shimokawa, 2007). According to the vegetation characterization at the soil survey sites (Figure 1), the dominant tree species (tree height is no less than 3 m) was *Lithocarpus edulis* and the chief tree shrub species (tree height is less than 3 m) were *Eurya japonica* Thunb. and *Ligustrum japonicum*. Tree height and breast height diameter of the dominant tree species and shrub layers increased with increasing distance from Minamidake crater. Dry density of the surface layer was between 1.25 g cm^{-3} and 1.89 g cm^{-3} from 2.40 km to 2.95 km from Minamidake crater. Regression analysis showed that the correlation coefficient between distance from Minamidake crater and surface layer dry density was 0.71, with an ANOVA statistical significance and correlation of 0.1%.

Shimokawa and Jitousono (1987) showed tephra thickness and tephra surface layer dry density accumulated in the period 1972 to 1983 decreased with increasing distance from the Minamidake crater. These results are similar to the results of the present study.

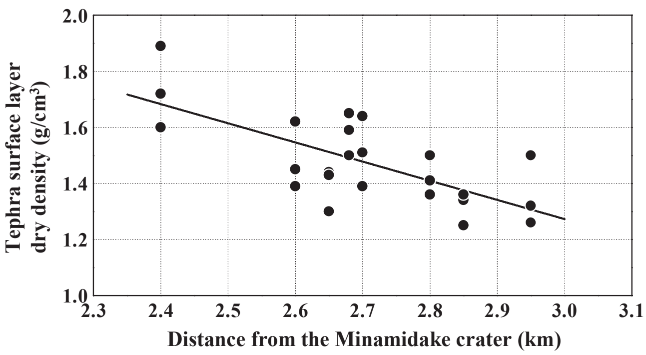

Figure 5: Dry density of tephra surface layer according to distance from the Minamidake crater

Figure 6 shows post-1972 tephra surface pH according to distance from Minamidake crater. The pH of the surface layer decreased with increasing distance from Minamidake crater. The pH of the surface layer was between 3.71 and 4.38 over the distance 2.40 km to 2.95 km from the Minamidake crater. Regression analysis showed that the correlation coefficient between distance from the Minamidake crater and pH of the tephra surface layer was 0.60, with a statistical significance of 1 %. Fujita and Nakata (2001) showed that as vegetation succession progressed, soil pH decreased. According to the vegetation survey at the soil survey sites (Figure 1), vegetation succession progressed with increasing distance from Minamidake crater.

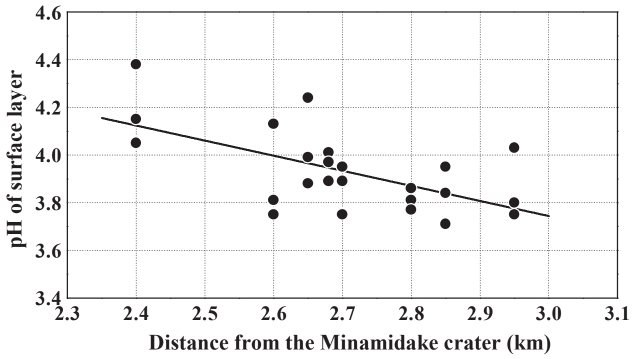

Figure 6: pH of surface layer according to distance from Minamidake crater

4 Conclusions

The results of the present study are as follows.

(1) Timberline altitude lowered as Mount Sakurajima volcanic activity commenced from 1972. The timberline rose slowly from 1997 to 2006 because of the recovery of vegetation caused by ebb in volcanic activity.

(2) According to the vegetation survey around the soil survey sites, tree height and breast height diameter of the main tree species in the tree and shrub layers increased with increasing distance from Minamidake crater, and vegetation succession progressed with increasing distance.

(3) The thickness of tephra, and the dry density and pH of the post-1972 tephra surface layer decreased with increasing distance from Minamidake crater.

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