海岸林学会誌 (*Journal of the Japanese Society of Coastal Forest*) 11 (1) : 1-6, 2012

Impact of volcanic activity in the Showa crater since June 2006 on growth of Japanese black pines on Sakurajima Volcano, Japan

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

Abstract: To study the impact of volcanic activity in the Showa crater since June 2006 on growth of Japanese black pines on Sakurajima Volcano, we conducted investigations of growth rings of Japanese black pines and of soil pH and volcanic ash deposition during 2003 and 2010. We established three experimental sites at 330 m, 70 m and 20 m above sea level, respectively. These experimental sites are most influenced by volcanic activity from the Showa crater. The annual average volcanic ash thickness at the experimental sites during the period of heightened volcanic activity (2008 to 2010) was greater than that during the period of low activity (2003 to 2007). Moreover, the growth ring width index of Japanese black pines during the period of low activity was greater than that during the period of heightened volcanic activity. It is clear that volcanic activity in the Showa crater since 2008 has affected the growth environment of Japanese black pines.

1 Introduction

The Minamidake crater of Sakurajima Volcano, located in southern Kyushu, Japan, has continued to be volcanically active for more than 50 years since October 1955. Simultaneously, eruption from the Showa crater, located southeast of the Minamidake crater, was generated on June 2006 after 58 years of inactivity. A small-scale pyroclastic flow was generated in February 2008 with the first explosive eruption from the Showa crater. In contrast with the considerable decline in volcanic activity of the Minamidake crater since 2003, volcanic activity in the Showa crater since 2008 has increased markedly (Kagoshima Local Meteorological Observatory, 1955–2010).

The activation of volcanic activity in the Showa crater of Sakurajima Volcano has caused the decline of Japanese black pines distributed widely from the hillslope to the coastal area following the increased emission of volcanic ash and gas. The decline of the Japanese black pines on the hillslope has accelerated erosion, and consequently debris and mud flows have often occurred in the rivers located on the Sakurajima Volcano. Moreover, the decline of the Japanese black pines in the coastal area of Sakurajima Volcano has caused a decline in the disaster prevention function of Japanese black pines in the coastal forest, and consequent damage from storms and salt has occurred on farms and orchards located on the lower slopes of Sakurajima Volcano.

The purpose of this study was to study the impact of volcanic activity in the Showa crater from June 2006 on growth of Japanese black pines on Sakurajima Volcano. The studies of Eggler (1967), Segura *et al.* (1995), Terazawa *et al.* (2000) and Teramoto and Shimokawa (2008) demonstrated the occurrence of temporal changes in growth rings and the growth ring width index following volcanic eruptions, based on the dendrochronological method. Few studies have been conducted on growth rings and the growth ring width index following volcanic eruptions. Thus, generation of additional data is required in the future.

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

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

2 Volcanic activity of Sakurajima Volcano since 1955

Sakurajima Volcano, which is one of the most active volcanoes in Japan, has been continuously active with frequent and lively small-scale eruptions since October 1955. The volcanic activity involves eruptions of volcanic ash and gas from the Minamidake crater and has continued for more than 50 years. Furthermore, the Showa crater of Sakurajima Volcano, located southeast of the Minamidake crater, begun to erupt in June 2006 after being dormant for 58 years.

Figure 1 (a) shows the temporal change in the annual frequency of explosive eruptions from the Minamidake crater of Sakurajima Volcano in the period from 1955 to 2010 (Kagoshima Local Meteorological Observatory, 1955–2010). The volcanic activities of the 1950s and 1960s were relatively gentle. However, from 1972, the activity increased. The annual frequency of explosive eruptions resulting from Minamidake crater during 1974 and 1986 exceeded 200. Moreover, the annual frequency of explosions in 1985 was 474, the largest annual value for the period from 1955 to 2010. Since 2003, the annual frequency of explosive eruptions resulting from Minamidake crater has decreased remarkably.

Figure 1 (b) shows the temporal change in the annual frequency of explosive eruptions from the Showa crater of Sakurajima Volcano in the period from 2006 to 2010 (Kagoshima Local Meteorological Observatory, 2006–2010). The first explosive eruption from the Showa crater since the 2006 eruption was generated in February 2008. Since 2008, the activity has increased. The annual frequency of explosive eruptions in 2010 was 896, the largest annual value for the period from 2008 to 2010. Thus, the annual frequency of explosive eruptions in 2010 from the Showa crater (896) was greater than that of the Minamidake crater in 1985 (474). The scale of the explosive eruptions from the Showa crater is smaller than that from the Minamidake crater, although the frequency of explosive eruptions from the Showa crater is greater than that from the Minamidake crater (Kagoshima Local Meteorological Observatory, 2006–2010).

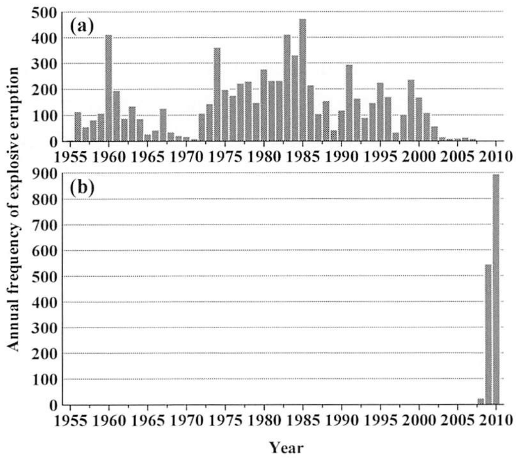

Figure 1: Temporal changes in the annual frequency of explosive eruptions from the Minamidake crater (a) and the Showa crater (b) of Sakurajima Volcano in the period from 1955 to 2010

3 Study area and methods

3.1 Overview of the study area and experimental sites

The study area is located on Sakurajima Volcano (Figure 2). Sakurajima Volcano has a circumference of 52 km and an area of 80 km^2. The topography below 300 m above sea level (a.s.l.) in the study area is hillslope and plateau. The topography from 300 m to 500 m a.s.l. consists of a mixture of hillslope and steep slope. The topography at 500 m a.s.l. and above is steep slope. The vegetation below about 600 m a.s.l. consists of broadleaf trees and *Pinus thunbergii* of artificial tree. The vegetation at 600 m a.s.l. and above consists of herbs and shrubs. The summit of Sakurajima Volcano is a bare slope.

To investigate the impact of volcanic activity in the Showa crater since June 2006 on growth of Japanese black pines on Sakurajima Volcano, three experimental sites were established at 330 m, 70 m and 20 m a.s.l., respectively (Figure 2). In this paper, we refer to the experimental site with an altitude of 330 m as 'Yunohira', situated to the west of Sakurajima Volcano (Photo 1 (a), Figure 2), the experimental site with an altitude of 70 m as 'Kurokami', situated to the east of the volcano (Photo 1 (b), Figure 2), and the experimental site with an altitude of 20 m as 'Arimura', situated to the south of the volcano (Photo 1 (c), Figure 2). These sites are most affected by volcanic activity from the Showa crater. The geological composition of the experimental sites consists of a 1914 Taisho lava layer or a 1946 Showa lava layer covered with a soil layer, a volcanic ash layer and a pumice layer.

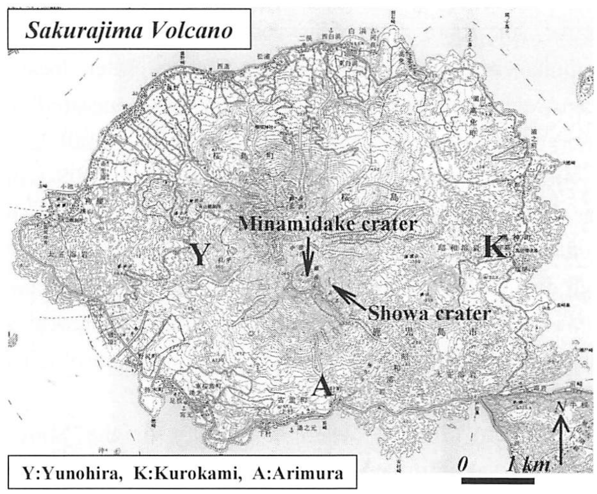

Figure 2: Location of the study area and experimental sites

Figure 3 shows the annual amount of volcanic ash deposition measured at Yunohira, Kurokami and Arimura between 1978 and 2010 (Kagoshima Prefecture, 1978–2010). The annual amount of volcanic ash deposited between 1978 and 1992 was substantial, because the Minamidake crater was volcanically active since 1972. The annual amount of volcanic ash measured at Yunohira and Kurokami in 1985 was about 118 kg m^{-2} and 80 kg m^{-2}, respectively, the largest annual values for the period from 1978 to 2010. The annual amount of volcanic ash measured at Arimura in 1986 was about 85 kg m^{-2}, the largest annual value for the period from 1978 to 2010. Since 1993, the annual amount of volcanic ash deposition has decreased.

Moreover, since 2003, the annual amount of volcanic ash deposition has decreased remarkably because of a substantial decrease in the frequency of explosive eruptions from Minamidake crater (Figure 1 (a)). The annual amount of volcanic ash deposition has increased, because volcanic activity from the Showa crater has increased since 2008 (Figure 1 (b)). With consideration of the changes in volcanic activity of Sakurajima Volcano (Figure 1 (a) and (b)), the bulk of volcanic ash deposition since 2008 is considered to have originated from the Showa crater.

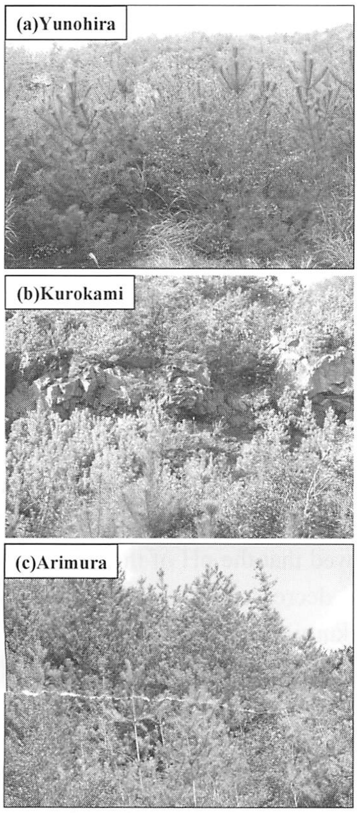

Photo 1: Conditions at the experimental sites

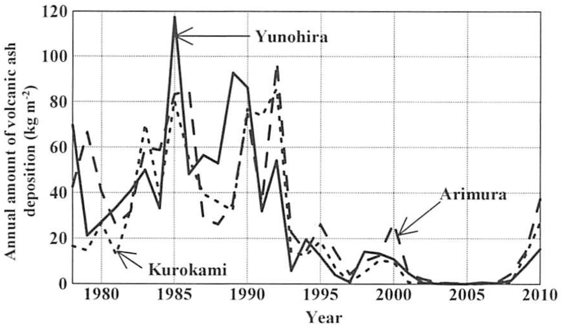

Figure 3: Temporal changes in the annual amount of volcanic ash measured at Yunohira, Kurokami and Arimura between 1978 and 2010

3.1 Methods

Soil and volcanic ash investigations were conducted in December 2010 and January 2011. Soil survey and pH measurements were conducted on samples collected from the volcanic ash layer on slopes covered by Japanese black pines. The investigation of volcanic ash distribution and deposition was conducted through observation of soil profile. Five soil profiles were investigated in each experimental site (Figure 2, Photo 1 (a), (b) and (c)).

According to volcanic ash deposition conditions such as tone, density, hardness and humus content based on the observation of the soil profile, the volcanic ash deposition since 2003 was divided into two layers. Since the lower layer of volcanic ash contained much humus, it seems that the lower layer was accumulated during the period of low volcanic activities from 2003 to 2007 (Figure 1 (a) and (b), Figure 3). It seems that the upper layer was accumulated during the period of heightened volcanic activities of the Showa crater from 2008 to 2010 (Figure 1 (a) and (b), Figure 3). Thus, changes of volcanic activities influence the characteristics of volcanic ash considerably (Shimokawa and Jitousono, 1987, Teramoto *et al.*, 2005). The soil profile was established on the slope that was near to flatness limited to sheet erosion. The thickness of volcanic ash deposited since 2003 was measured. pH measurement of the volcanic ash 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. The samples were collected from the volcanic ash layer of the periods of heightened volcanic activities from 2008 to 2010 and low activities from 2003 to 2007, respectively.

Moreover, to study the impact of volcanic activity of the Showa crater from June 2006 on growth of Japanese black pines, we made the standard growth ring curve of the Japanese black pines in the experimental sites. The standard growth ring curve can remove the differences in growth property of tree and the effect of change in growth ring width accompanying competition among the surrounding trees (Japan Forest Technology Association, 2001). Preparation method of the standard growth ring curve was conducted as follows. We collected two wood block samples by using a borer auger at a sloping direction and a perpendicular direction to the sloping direction at about 1.2 m height of a Japanese black pine tree from the ground. The growth ring width was shown in the average value of growth ring width measured in the sloping and perpendicular directions. Moreover, the temporal change in the growth ring width was approximated by exponential function, and the growth ring width index was found from dividing a growth ring width of each year by a growth ring width of each year estimated by an approximated curve. The growth ring width index in each year was found from five Japanese black pines measured in each experimental site, and the standard growth ring curve was made by averaging these growth ring width indexes. Tree age of Japanese black pines collected the wood block samples was in the range of 8 to 12 years.

4 Results and discussion

4.1 Impact of volcanic activity in the Showa crater on growth environment of Japanese black pines

Table 1 shows the annual average thickness and pH of volcanic ash layer during periods of both heightened (2008 to 2010) and low (2003 to 2007) volcanic activities in the experimental sites. The values of the thickness and pH shown in Table 1 show the minimum, maximum and average values.

Table 1: Annual average thickness and pH of the volcanic ash layer at the experimental sites during periods of heightened and low volcanic activity

Period	Annual average thickness of volcanic ash layer (cm)			pH of volcanic ash layer		
	Yunohira	Kurokami	Arimura	Yunohira	Kurokami	Arimura
Heightened volcanic activity (2008 to 2010)	0.8-1.3 (1.1)	2.3-3.3 (2.8)	2.7-4.0 (3.1)	4.4-4.7 (4.6)	4.2-4.8 (4.8)	4.0-5.2 (4.5)
Low volcanic activity (2003 to 2007)	0.2-0.4 (0.3)	0.6-0.8 (0.7)	0.6-1.0 (0.8)	3.8-4.2 (4.0)	4.0-4.3 (4.2)	3.4-4.5 (4.0)

The minimum, maximum and average values of the annual average volcanic ash thickness during the period of heightened volcanic activities were greater than those during the period of low activities in the experimental sites. The annual average thickness of the volcanic ash layer during the period of heightened volcanic activities was about four times greater than that in the period of low activities. The annual average thickness of the volcanic ash layer during the two periods in Arimura was greater than that in other experimental sites. Teramoto and Shimokawa (2010a) studied the thickness of volcanic ash layer during periods of both heightened (1972 to 1993) and low (1994 to 2008) volcanic activities of the Minamidake crater in the northern flank of Sakurajima Volcano, and showed that the annual average thickness of volcanic ash layer during the period of heightened volcanic activities was greater than that during the period of low activities.

The minimum, maximum and average values of the pH in volcanic ash layer during the period of heightened volcanic activities were greater than those during the period of low activities in the experimental sites. The observations of the pH indicated that the greater the effect of volcanic activity from Sakurajima Volcano, the greater the values of the pH became. The decrease in the effect of volcanic activity causes the recovery of the growth environment of Japanese black pines (Teramoto and Shimokawa, 2010b). Teramoto and Shimokawa (2010b) showed that the pH of the surface layer became smaller with decreased effect from the Minamidake crater of Sakurajima Volcano. Moreover, Fujita and Nakata (2001) indicated that as succession of vegetation progressed, pH of the soil became smaller. These results are similar to the results of the current study.

4.2 Impact of volcanic activity in the Showa crater on growth ring of Japanese black pines

Figure 4 shows the temporal changes in the growth ring width index during periods of both heightened (2008 to 2010) and low (2003 to 2007) volcanic activities in Yunohira, Kurokami and Arimura, respectively. Moreover, Table 2 shows growth ring width index during periods of both heightened and low volcanic activities in the experimental sites. The minimum, maximum and average values of the growth ring width index during the period of low activities were greater than that during the period of heightened volcanic activities in the experimental sites. It suggests that the growth environment of Japanese black pines during the period of low activities was finer than that during the period of heightened activities. The annual average thickness of volcanic ash layer during the period of low volcanic activities was smaller than that during the period of heightened activities (Table 1), and more humus were formed in volcanic ash layer during the period of low activities. These are harmony with the results of Figure 4.

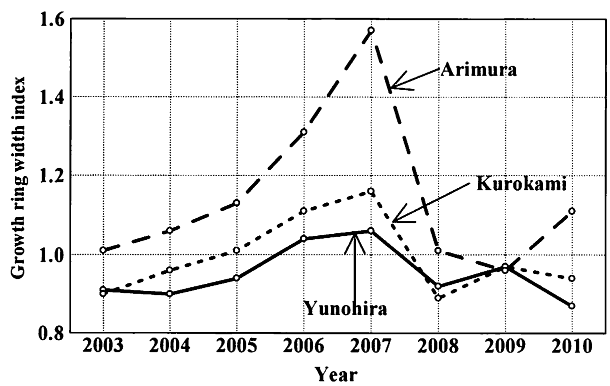

Figure 4: Temporal changes in the growth ring width index during periods of both heightened and low volcanic activities in the experimental sites.

Table 3 shows rainfall and temperature conditions during periods of both heightened (2008 to 2010) and low (2003 to 2007) volcanic activities. These datum were collected by a Kagoshima local meteorological observatory, situated to the west at a location of about 5 km away from Sakurajima Volcano (Kagoshima local meteorological observatory, 2003-2010). Meteorological conditions during the two periods showed a nearly similar tendency.

The effect of the ebb and flow of volcanic activity in Sakurajima Volcano on the change in the growth ring width index of Japanese black pines was conducted by Teramoto and Shimokawa (2008). They showed that the growth ring width index of Japanese black pines during period of low volcanic activity was larger than that during period of heightened activity. Moreover, they indicated that the reason for increase in the growth ring width index during period of low volcanic activity was thought to be due to the recovery of the vegetation caused by improvement of the growth environment of vegetation following the ebb of volcanic activity.

Table 2: Growth ring width index at the experimental sites during periods of heightened and low volcanic activity

Period	Growth ring width index		
	Yunohira	Kurokami	Arimura
Heightened volcanic activity (2008 to 2010)	0.87-0.97 (0.92)	0.89-0.97 (0.93)	0.96-1.11 (1.03)
Low volcanic activity (2003 to 2007)	0.90-1.06 (0.97)	0.90-1.16 (1.03)	1.01-1.57 (1.22)

Table 3: Comparison of meteorological conditions during periods of heightened and low volcanic activity

Period	Yearly rainfall mm	Maximum rainfall per one-hour interval mm	Yearly average daily temperature degree
Heightened volcanic activity (2008 to 2010)	1988-2420 (2208)	58-77 (67)	18.5-19.3 (19.0)
Low volcanic activity (2003 to 2007)	1530-2942 (2273)	35-54 (44)	18.7-19.0 (18.9)

References

[1] Eggler W. A. (1967): Influence of volcanic eruptions on xylem growth patterns, *Ecology*, 48, pp.644-647.

[2] Fujita, E. and Nakata, M. (2001): Changes in vegetation and soil properties caused by mixture of deciduous broad-leaved trees in Japanese black pine (*Pinus thunbergii* Parl.) stand at coastal sand dune: A case study in Kaetsu district, Niigata prefecture, *Journal of the Japanese Forestry Society*, 83(2), pp.84-92. (in Japanese with English abstract)

[3] Japan Forest Technology Association (2001): Encyclopedia of forest and forestry, *Maruzen Co. LTD.*, 1250pp. (in Japanese)

[4] Kagoshima Local Meteorological Observatory (1955-2010): Observed data:

[5] Kagoshima Prefecture (1978-2010): Observed data:

[6] Segura G., T. M. Hinckley and L. B. Brubaker (1995): Variation in radial growth of declining old-growth stands of *Abies amabilis* after tephra deposition from Mt. St Helens, *Canadian Journal of Forest Research*, 25, pp.1484-1492.

[7] Shimokawa, E. and Jitousono, T. (1987): Rate of erosion on tephra-covered slopes of volcanoes, *Transactions of Japanese Geomorphological Union*, 8, pp.269-286. (in Japanese with English abstract)

[8] Teramoto, Y., Shimokawa, E. and Jitousono, T. (2005): Effects of the difference of volcanic activity on erosion rate by sheet erosion in Sakurajima volcano, *Journal of Japan Society of Erosion Control Engineering*, 57(5), pp.65-68. (in Japanese)

[9] Teramoto Y. and Shimokawa E. (2008): Effect of volcanic activity on structure and the diameter-growth of a Japanese black pine forest on Mount Sakurajima, *Journal of the Japanese Society of Coastal Forest*, 7(2), pp.33-36. (in Japanese with English abstract)

[10] Teramoto Y. and Shimokawa E. (2010): Temporal changes in vegetation and soil environment caused by volcanic activity of Mount Sakurajima, *Journal of the Japanese Society of Coastal Forest*, 9(2), pp.75-78.

[11] Teramoto Y. and Shimokawa E. (2011, in print): Effect of volcanic activity on physical properties of volcanic ash on the hillside slope of Mount Sakurajima, *Journal of the Japanese Society of Coastal Forest*, 10(1), pp.1-5.

[12] Terazawa K., Umeki K. and Yasaka M. (2000): Effects of ashfall erupted from Usu Volcano in 1977 on the surrounding forests (Ⅱ) Radial growth and stem form of trees, *Bulletin of the Hokkaido Forestry Research Institute*, 37, pp.11-25. (in Japanese with English abstract)

〔Received April 28th, 2011　Accepted June 11th, 2012〕