Erosion of Mountain Hiking Trail Over a Seven-Year Period in Daisetsuzan National Park, Central Hokkaido, Japan

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Abstract—Erosion of mountain hiking trails was investigated in Daisetsuzan National Park over a seven-year period. The amount and rate of erosion were different in the two typical landscape components. Cross-section diagrams revealed that trail depth became deeper in snowy vegetated areas than in wind-beaten bare ground areas. The existence and timing of runoff from snowmelt seemed to be important to differential erosion. Trail slope is another factor contributing to erosion. Needle ice or saturation of surface soil appeared to cause side wall erosion. Installation of ropes along the trails made hikers stay on the trail, helping to mitigate erosion.

It is important to observe changes in nature over time for understanding human impacts and for devising effective management methods for conservation. Many studies centering on the degradation of plants and soils due to recreational impacts have been conducted in Europe and the United States. Some studies paid special attention to trail degradation (Bayfield 1973; Bratton and others 1979; Gellatly and others 1986; Price 1985). Others described trail conditions and tried to identify factors contributing to erosion. Experimental studies have been conducted in order to detect human impact. For example, Quinn and others (1980) worked on mechanics of trampling, Cole (1987) observed vegetation recovery after experimental trampling, and Coleman (1981) and Garland and others (1985) investigated relationships between trail deterioration and contributing factors. Yoda (1991) used cross-section diagrams to identify how, when and what part of the paths were eroded and to distinguish the human and natural causes of erosion in Daisetsuzan National Park, northern Japan. Yamada (1993) also used the cross-section diagrams to visualize erosional characteristics of the Mt. Hakusan trail, central Japan.

However, not many studies have been conducted with long-term observations, which are necessary for design of effective and efficient management actions. Long-term studies include Lance and others (1989), who observed trail widening over a five year period and the experiment by Gellatly and others (1986) and Cole (1987) trying to detect the recovery of soil properties and vegetation. Bell and Bliss (1973) reported on the establishment of plant cover over 31 years in alpine tundra and subalpine meadow. In Japan few studies deal with long-term human impacts on nature with the exception of Watanabe and Fukasawa (1998).

Based on data observed in 1990 and 1997, this study compares the degree of trail erosion in the two major landscape components of snowy vegetated areas and wind-beaten bare ground areas. It also discusses the tendencies of erosional characteristics and the causes of erosion in these landscape components.

Study Area

Topography and Geology

Daisetsuzan National Park is situated in central Hokkaido, northern Japan (fig. 1). This area was designated as a national park in 1934. Its area is about 2,300 km^2, making it the largest national park in Japan. It is composed of volcanic mountains including Mt. Asahidake (2,290m), the highest peak in Hokkaido. The summit area is covered with the ejecta from Quaternary volcanic activities (Hokkaido Development Agency 1966). In most places the ground surface is covered with volcanic ash and pyroclastic materials.

A variety of periglacial landforms including permafrost, earth hummocks, palsas, patterned ground, solifluction lobes and block fields are spread throughout the summit area above the timberline (Fukuda and Sone 1992; Sone 1992; Takahashi 1990).

Climate

The mean annual temperature observed on the top of Mt. Kurodake (1,984 m) from October 1989 to September 1990 was -2.3°C. The lowest temperature was -21.8°C in January, and the highest one was 18.7°C in July. From October to June is a harsh season, with severe cold and snowfall. The monthly mean temperature was below zero from October 1989 to April 1990, and the study area was completely under snow until early May in 1990. Winter snow usually starts disappearing in May with some snow patches remaining year round.

Vegetation

The timberline is located at about 1,650m in this area (Okitsu and Ito 1984). Japanese stone pine (*Pinus pumila*), Japanese mountain-ash (*Sorbus matsumurana*) and other alpine vegetation occupy the alpine belt. Some species found

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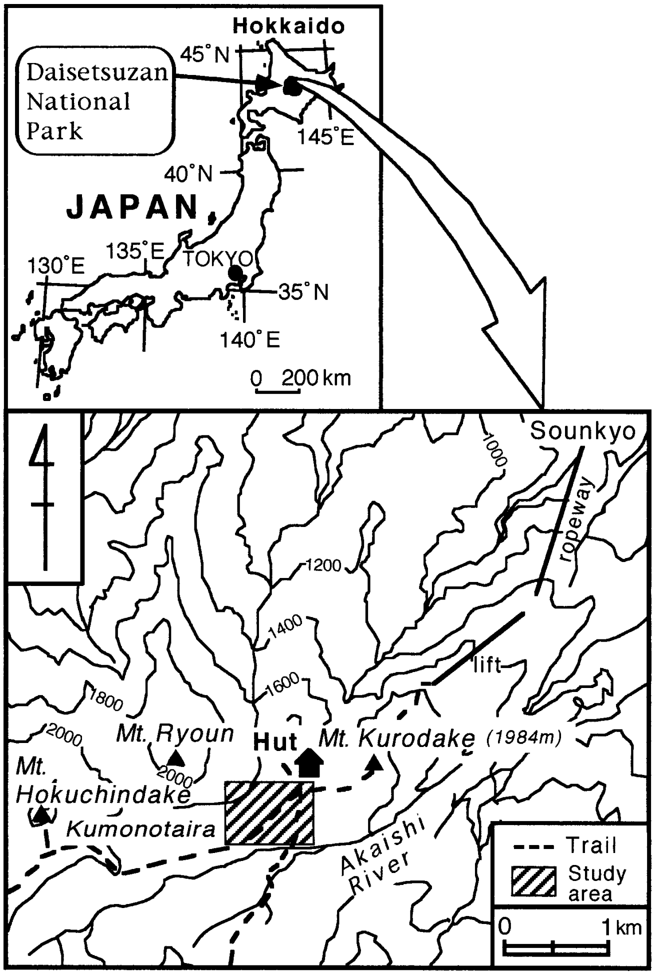

Figure 1—Study area.

on the Kumonotaira plateau, where trails were surveyed, are typical circumpolar arctic plants (Sakai and Otsuka 1970). According to Ito and Sato (1981) the main natural vegetation of wind-beaten bare ground areas are dwarf scrub such as alpine rosemary (*Arcterica nana*), alpine-azalea (*Loiseleuria procumbens*), and alpine blueberry (*Vaccinium uliginosum*). Snowy vegetated areas are mainly covered with communities of wedge-leaved primrose (*Primula cuneifolia*), Japanese mountain avens (*Sieversia pentapetala*) and Aleution mountain-heather (*Phyllodoce aleutica*).

Number of Visitors

The number of visitors to Daisetsuzan National Park increased from 410,000 in 1960 to 5,240,000 in 1987 (Oguchi and others 1989). In 1997, 42,814 people visited Mt. Kurodake (data collected by the Kamikawa Forest Office). Because of the severe climate, most visitors come during the summer season when there is little snow (mid June to September).

Trail Management

At the start of the hiking season, park staff installs ropes along the trails to keep hikers on the trails. They put away ropes at the end of visiting season because of heavy winter snowfall. Each year they install ropes at slightly different places, if replacement of the walking paths is necessary. The few staff members are usually busy watching for the theft of alpine plants in this area, and they do not have enough time to fix degraded trails. Presently no measures have been taken to maintain or fix degraded trails with the exception of less costly small-scale but ad hoc works.

Methodology

The study area includes two typical landscape components: wind-beaten bare ground and snowy vegetated areas (fig. 2). Snowy vegetated areas are covered by either shrub trees or snowy bed community vegetation. Since erosion in the wind-beaten bare ground areas seemed to vary from that in snowy vegetated areas, cross-sectional profiles of the trails were measured in both landscape components. Initially in September 1990, nine cross sections in the wind-beaten bare ground area (cross-sections 1-6 and 10-12) and ten cross sections in the snowy vegetated area (cross-sections 7-9 and 13-19) were measured. These sections were remeasured in June, July or August of 1997.

For accurate repeat measurement at the same site, a pair of aluminum angle stakes was installed at each site on both sides of the trail as a fixed point to observe secular change (fig. 3). To measure the profiles, a fishing line is stretched between the pair of angles, and a tape-measure with a weight attached perpendicular to the ground provides depth (in centimeters) between the line and the trail surface. Depth was measured at 10-centimeter intervals along the line. Thus, the profile of the trail surface was obtained. The amount of erosion or accumulation is recognized by the

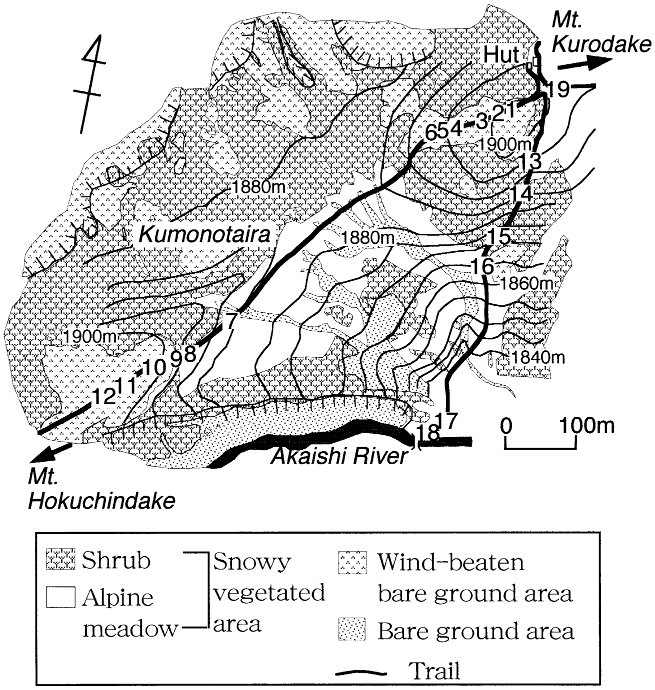

Figure 2—Landscape components and locations of cross sections 1-19.

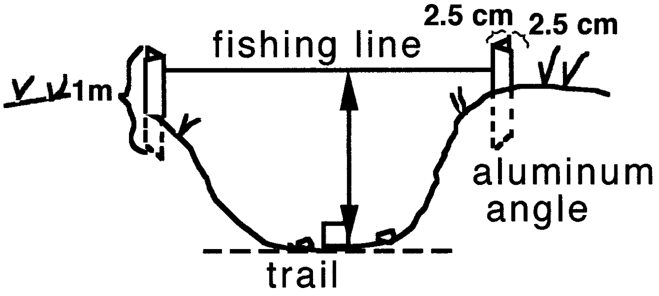

Figure 3—Method for measuring a trail surface.

change in area of each cross section, as reported by Cole (1983).

Patterns and timing of snowmelt were also examined in the field to determine the timing and duration of runoff over the trail surface. The size of each snow patch was measured using a tape-measure and a compass in the field. Measurements were repeated at one month intervals.

Results

Degree of Erosion

All ten cross sections from the snowy vegetated area revealed more erosion than accumulation. The most active erosion occurred at cross-section 7, in the snowy vegetated area, near the head of the gully at the bottom of the trails (fig. 4). Relative height of the gully head at cross-section 7 on the left attained about 80 cm, and the area eroded was about 7,200 cm^2 over the seven years.

This was not the case for cross sections in the wind-beaten bare ground area. For example, cross-section 6 had 300 cm^2 of erosion and 1,600 cm^2 of accumulation in the trail (fig. 5). The deepest erosion was found on the left portion of cross-section 12, becoming about 30 cm deeper in 1997 than in 1990 (fig. 6). Here the eroded area of the trail was 2,200 cm^2, but the area of soil accumulation on the right side was 2,000 cm^2.

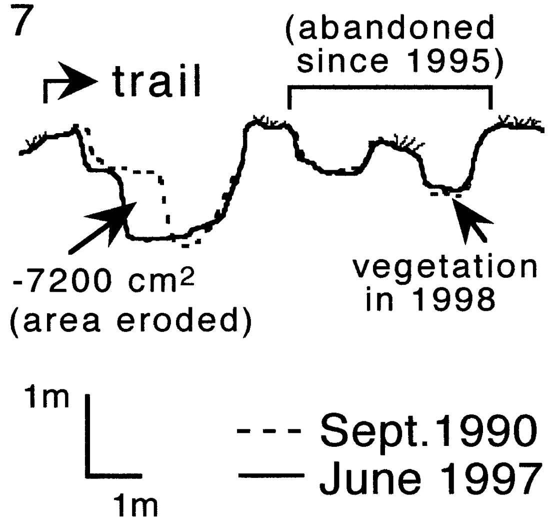

Figure 4—Change in the trail surface at cross-section 7.

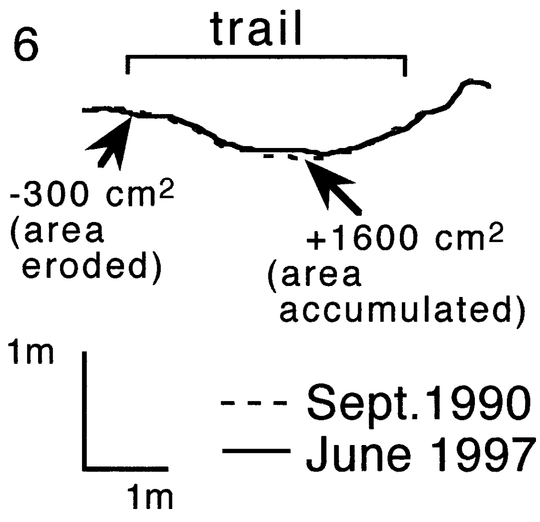

Figure 5—Change in the trail surface at cross-section 6.

Characteristics of Erosion

The erosion was mainly divided into three types in the snowy vegetated area: gully type, valley-shape type and side-wall collapse type. Gully development was observed at section 17 on the left (fig. 7). It was subject to heavy runoff, as snow melts from a nearby patch until late July, becoming 22 cm deeper during the seven years. Other gullies have not been developed at such a rapid pace. Valley-shaped cross sections, such as cross-sections 13 or 14, where people walk on the bottom of the trail showed erosion along the trail bottom (fig. 8). Side-wall collapse was observed at cross-sections 7, 8, 13 and 14 (figs. 4, 9 and 8). In the wind-beaten bare ground area, half of the cross-sections showed small erosion on the trail surface (cross-sections 1, 2, 3, 4, and 11) (fig. 10).

Trail surfaces in the snowy vegetated area had a V- or U-shaped cross section (gully or valley-shape type), if we envision the original ground surface (fig. 11). The wind-beaten bare ground area, on the other hand, had a rather flat cross section. The average ratio of depth to width of the

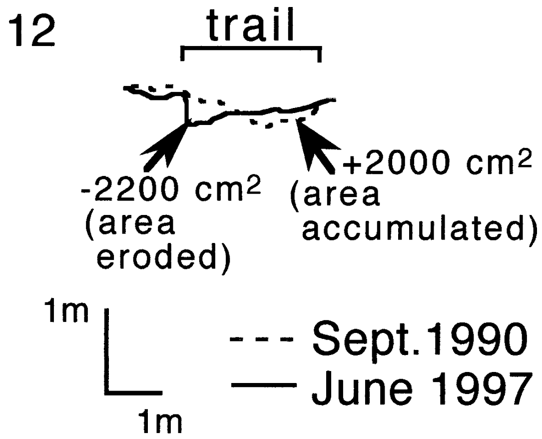

Figure 6—Change in the trail surface at cross-section 12.

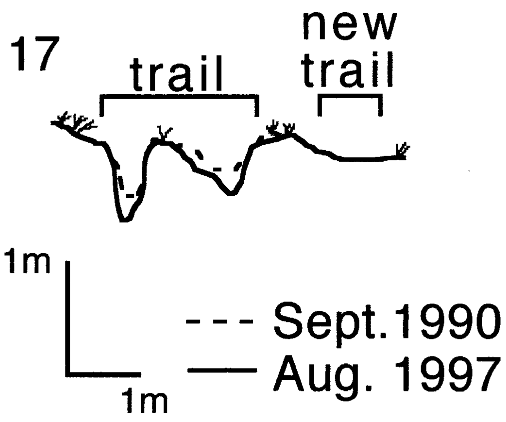

Figure 7—Change in the trail surface at cross-section 17.

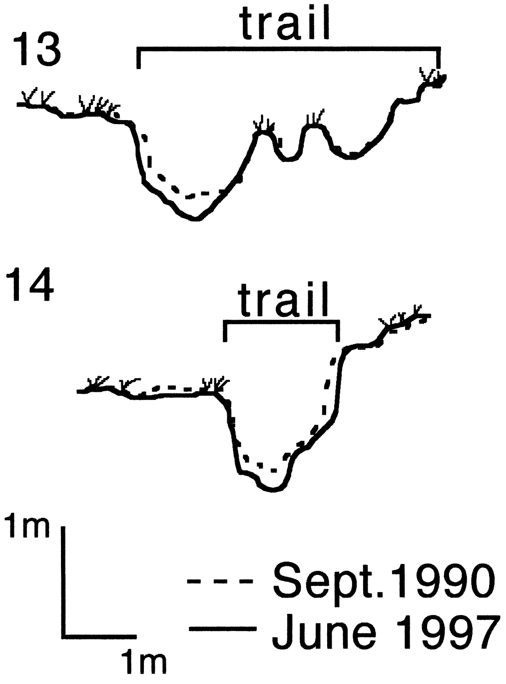

Figure 8—Changes in the trail surface at cross-sections 13 and 14.

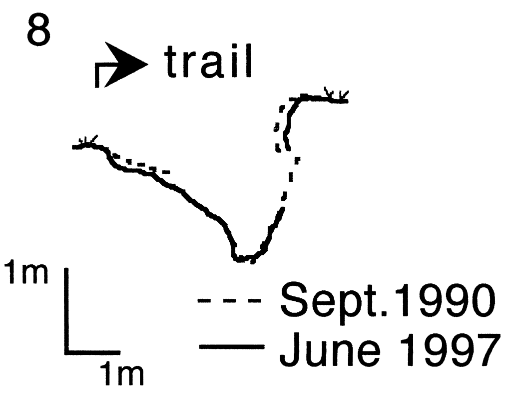

Figure 9—Change in the trail surface at cross-section 8.

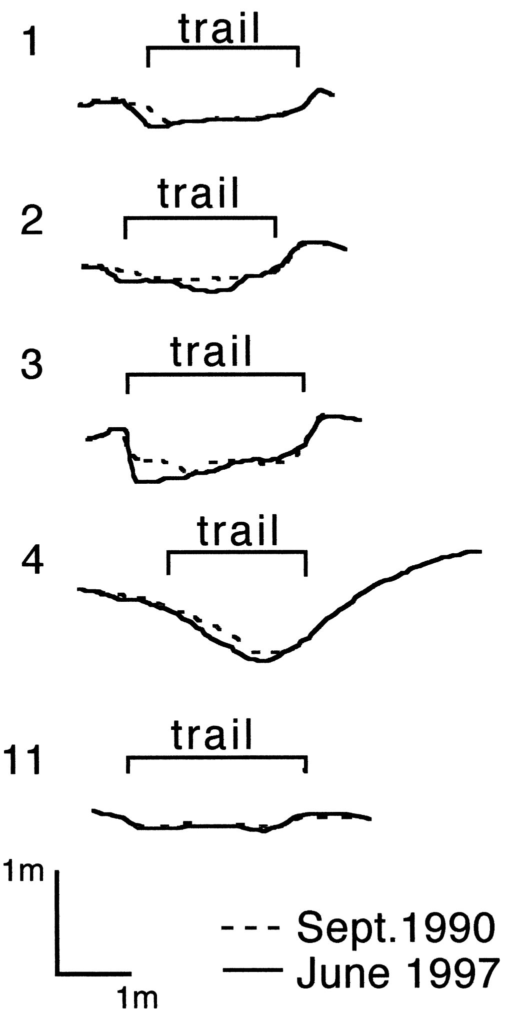

Figure 10—Cross-sections 1, 2, 3, 4, and 11.

eroded trails in snowy vegetated areas was 0.39 (range from 0.06 to 1.00), whereas the average ratio in wind-beaten bare ground areas was 0.18 (range from 0.05 to 0.50). Table 1 shows that trail erosion is more severe in snowy vegetated areas than that observed in wind-beaten bare ground areas. The average amount of erosion in snowy vegetated areas is about 1.9 times larger than in wind-beaten bare ground areas.

Timing of Snowmelt

Snowmelt began nearly one month earlier in wind-beaten bare ground areas than in snowy vegetated areas. The snow began to disappear in the middle of June in 1997 in the wind-beaten bare ground area on the ridge, where cross-sections 1-6 and 10-12 were situated (fig. 12). Subsequently, snow melting went on to the down slope and snow drift areas. Snowmelt down to the Akaishi river in 1997 lasted until the end of July.

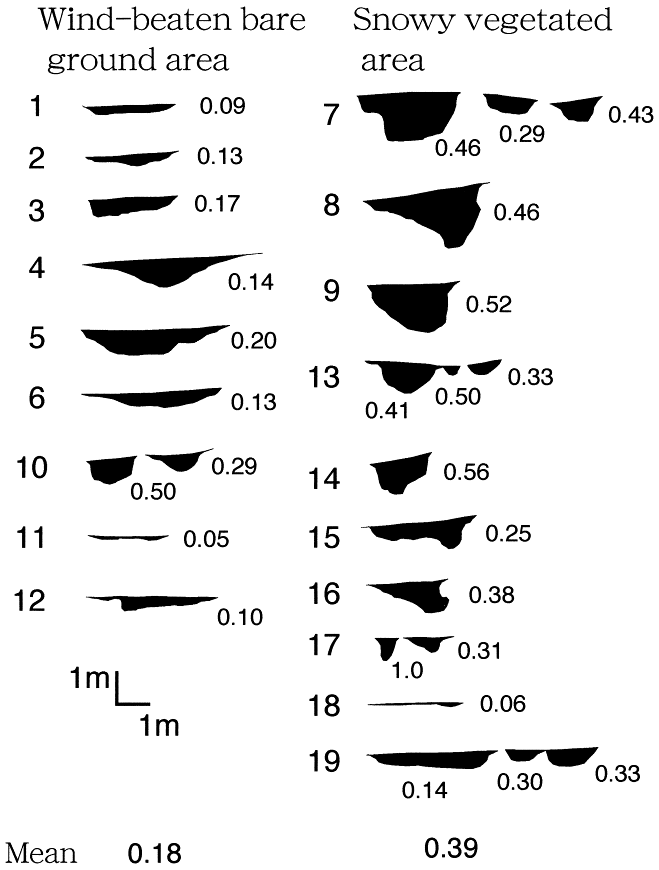

Figure 11—Comparison of the changes in the cross sectional profiles of the trail between the wind-beaten bare ground area and the snowy vegetated area. The figure denotes the ratio of the depth to the width of the eroded trail.

Mitigating Erosion

Installing trail side ropes helped mitigate soil erosion at some sites. Cross-section 10 is a multiple trail (fig. 13). A rope was installed between two paths to designate one path as abandoned. The presently used path on the right had a total of 2,400 cm^2 of erosion and 500 cm^2 of accumulation. The path on the left, abandoned for at least ten years, had soil accumulation of 300 cm^2 on the bottom.

Installing ropes is also useful for vegetation recovery. The abandoned trail in the middle and on the right at cross-section 7 in figure 4 has not been used for three years. There was no erosion, and monocotyledon and other plants had begun to grow on the abandoned trail surface. On the other hand, a new trail was developed on the right side of cross-section 17 due to rope installation (fig. 7). Vegetation was trampled and completely destroyed on the new trail.

Discussion

The study area is covered with loose volcanic materials such as easily erodable pumice and lapili. At cross-section 7 the most active erosion occurred near the gully head. In 1997 the cross-section was located 25 cm downstream from the gully head with the most active erosion due to the gully head retreat. Subsurface layers having different vulnerabilities to erosion will lead to changing erosion rates. Thus, long-term monitoring of erosion is important for forecasting and preventing sudden trail collapse.

Once established gully development continues due to surface runoff. For example, the most developed gully, at cross-section 17, was subject to continuous runoff from a nearby snow patch until the end of July 1997. At this site materials from the ground surface down to a depth of at least 1 m are primarily composed of sandy silt. With other environmental conditions remaining steady the trail surface will

Table 1—The slope angle and amount of erosion observed in trail cross-sections from the two different landscape components (wind-beaten bare ground area and snowy vegetated area) during 1990-1997.

Wind-beaten bare ground area (cross-section number)	Slope angle of the trail (°)	Amount of erosion (cm^2)	Snowy vegetated area (cross-section number)	Slope angle of the trail (°)	Amount of erosion (cm^2)
1	0.5	1200	7	11.5	10900
2	3.0	1800	8	6.0	3900
3	3.0	2600	9	8.0	4400
4	7.5	2000	13	14.0	3600
5	4.0	4700	14	10.0	3700
6	4.0	300	15	10.0	3100
10	4.5	2400	16	10.5	1900
11	2.0	800	17	1.0	2600
12	3.0	2200	18	0.5	700
			19	0.5	2900
average	3.5	2000	average	7.2	3770

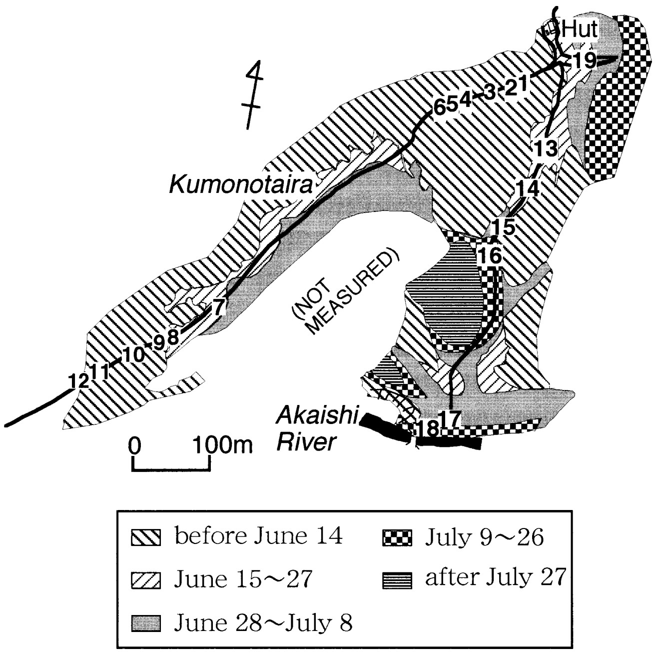

Figure 12—Timing of snowmelt in 1997.

erode continuously until a more erosion resistant layer is encountered. Many trails are now functioning as runoff streams for snowmelt and rain water. Therefore, the timing and the amount of snowmelt at each site are important factors in determining trail erosion rates.

The snowy vegetated area is usually developed on the middle or foot of the slope, and it is subject to greater and larger duration of surface runoff from a nearby snow patch. Although the slope angle is rather small, the amount of erosion at cross-section 17 was 2,600 cm^2. In this area surface runoff is a large contributor to erosion.

However, slope angle is another potential factor contributing to erosion. Coleman (1981) suggests that path slope is one of the variables contributing to depth of gullying on a trail. The wind-beaten bare ground area is located on the ridge and has a generally small slope. Cross-sectional sites surveyed in the wind-beaten bare ground area have slope angles from 0.5 to 7.5 degrees (table 1). The snowy vegetated areas have slope angles ranging from 0.5 to 14.0 degrees. Average erosion in the snowy vegetated area is about 1.9 times larger than that in the wind-beaten bare ground area (table 1).

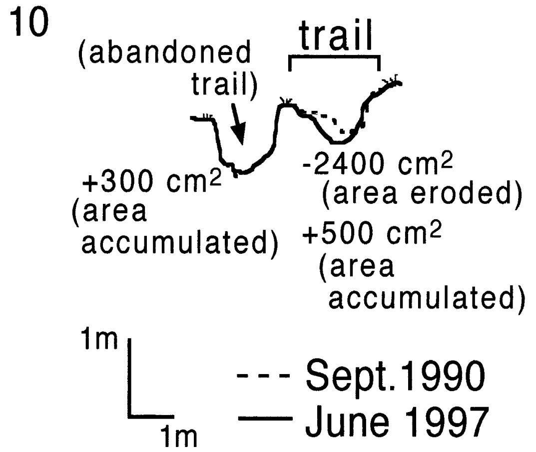

Figure 13—Change in the trail surface at cross-section 10.

The snowy vegetated area tends to be more vulnerable to erosion than the wind-beaten bare ground area in the study area. However, further study is needed to clarify the erosional contribution of each contributing factor (path slope and duration/amount of surface runoff) in the two landscape components.

Observations also suggest other erosion contributing factors. Needle ice erosion or detachment of saturated surface soil seems to have caused the side collapse of cross-sections 7, 13 and 14. This collapse is active during the snowmelt and freeze-thaw season and after heavy rainfall.

Observing trail erosion over the past seven years clearly demonstrates that the snowy vegetated area is more vulnerable to erosion than the wind-beaten bare ground area. This study also determined sites where active erosion is occurring and where immediate remediation measures should be taken.

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