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# 学 位 論 文 内 容 の 要 旨

Dissertation Abstract

博士（環境科学）

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## 学 位 論 文 題 名

Title of dissertation

Long-term three-dimensional analyses of trail degradation and proposal for a new partnership management framework in Daisetsuzan National Park, Japan

(大雪山国立公園における登山道荒廃の長期3次元解析と新たなパートナーシップ管理フレームワークの提言)

Many mountainous, protected areas, such as national parks worldwide, face trail erosion. Although the study of trail degradation is a niche field, research has been conducted in many countries, including Europe, the United States, Japan, and South Africa. However, the academic significance of the research has not often been questioned because the main objective of the research has been to solve problems related to national park management.

On the other hand, as the sustainable use and conservation of the natural environment in national parks have become more important than ever before, trail management has come to be faced with the need to promote science-based management. Basic methods for measuring mountain trails were established in the 1980s. However, because it has been extremely difficult to measure the volume of trail erosion. A conventional two-dimensional cross-sectional area has been calculated for years, even today. Recent technological advancement of Structure from Motion and Multi View Stereo photogrammetry, however, enabled to measure the eroded volume of land surface in

some research disciplines such as disaster science and archaeology. This approach is now used in trail science as well.

In mountainous national parks worldwide, stakeholders have made significant efforts to manage eroded trails. However, their effectiveness has not been evaluated. This study aimed to (1) create of high-definition trail data using Structure from Motion and Multi-View Stereo photogrammetry, (2) use high-definition trail data to reveal trail surface changes over long periods of time, for the first time in trail science, (3) discuss the effectiveness of the repair works, and (4) propose new partnership management framework and measures based on three-dimensional analyses in Daisetsuzan National Park, Japan.

This study was the first to capture three-dimensional changes in trail surface morphology over a long period of time, and this method has not only academic value but also contributes to the future management of national parks in the following ways.

This study enabled to visualize the results of repair work on a degraded section of trail. The results of the three-dimensional analysis identified a certain effectiveness of the repair work during 2017–2022. However, the effectiveness lasted for only approximately three years and was not permanent. Therefore, regular maintenance is necessary to ensure trail sustainability. In addition, the soil erosion rate calculated using the maximum erosion depth has increased from  $0.52 \text{ mm y}^{-1}$  (1923–1990) to  $44.4 \text{ mm y}^{-1}$  (2013–2022), suggesting the need for frequent observations. Trail maintenance through a combination of monitoring and repair work is vital. This study implies the need of regular maintenance and repair works. Furthermore, the role of hikers/trekkers is becoming increasingly important as will be discussed later.

Secondly, visualization of the results of the repair work will make it easier to communicate the significance of the repair work to volunteers and the public at large. This will encourage the acquisition of new volunteers, and by spreading the word to the public about the need for trail repair, it will make it easier to collect cooperative funds from trail users and foster a culture of donation. Volunteer trail maintenance is not only practiced in Japan, but also in many other countries with limited budgets, and visualization of the results of trail repair is of great significance in many mountainous national parks.

Thirdly, long-term monitoring is useful for prioritizing repair work. Long-term data have been obtained in two-dimensional cross sections in previous studies. However, the data obtained by the conventional cross-sectional method is only point data (information only at that point). On the other hand, the data obtained by the UAV method employed in this study can be used to point out where repair work should be prioritized among the more than 300 km of trails in the park. To realize this, it is highly desirable to establish the Daisetsuzan Foundation (tentative name) as soon as possible.

The approach taken by this study can be applied in mountainous national parks worldwide. National-park managers should utilize science-based datasets when they make a decision in prioritizing trail management/repair, to which this study will be beneficial.