学 位 論 文 内 容 の 要 旨/Dissertation Abstract

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学 位 論 文 題 名/Title of Dissertation

Relationships between functional traits and tree establishment after landslide disturbances in cool-temperate forests
（冷温帯林における山腹崩壊後の樹木定着と機能形質との関係）

The frequency and severity of disturbances have been changing significantly due to climate change. In fact, the frequency and severity of landslides triggered by extreme precipitation have increased globally in recent years. Post-landslide forests are generally harsh and stressful environments for tree regeneration. Therefore, understanding the life history strategies of plants after landslides is crucial for the effective restoration of forest ecosystems. The trait-based approach is a powerful tool for understanding the regeneration of plants under changing climate, because plant functional traits often relate to plant survival, growth, and the efficiency of plant resource-use strategy in post-disturbance forests. Particularly, plant roots are important for the tree regeneration in post-landslide forests, because, for example, they have a significant impact on slope stability to prevent landslides. However, we lack a clear understanding of the applicability of functional traits as a determinant of the success of plant regeneration in post-landslide forests, especially with weak evidence for root traits and tree performance. Furthermore, climate change, such as extreme precipitation, can also occur after landslides. Consequently, the harsh environment established after landslides and extreme precipitation can trigger multifactorial stress combinations for regenerating plants. The limited understanding of plant responses to such multiple environmental stresses makes it difficult to establish an effective restoration strategy for post-landslide forests under a changing climate. The purpose of this thesis was to explore the relationships between plant functional traits and plant performance after landslide disturbance under increasing precipitation.

In Chapter 2, the study examined the relationship among tensile strength (Tr) and morphological and structural traits of fine roots of the seedlings from a total of 15 tree species dominant in cool temperate forests. Fine root Tr, reflecting the mechanical strength of the root system, is an important functional trait for resistance to soil erosion after landslides. However fine root Tr is laborious to measure and shows large variations among tree species. Therefore, I aimed to determine powerful predictors of fine root Tr across a wide range of tree species in this study. This experiment was conducted in an experimental nursery in northern Hokkaido. My study revealed that total fine root biomass per tree individual had a significantly positive correlation with fine root Tr and served as a good predictor of fine root Tr across 15 tree species. These results streamline the evaluation of fine root Tr across various tree species, providing useful information for controlling soil erosion and improving shallow slope stability in cool temperate forests.

In Chapter 3, a two-year monitoring of tree seedlings regenerating was conducted in post-landslide forests of northern Japan. There are limited studies that investigated the predictive traits of three demographic properties (mortality, growth, and recruitment) of tree seedlings with special reference for both aboveground and belowground traits simultaneously. In this study, the correlations

between aboveground (leaf mass per area, leaf dry matter content, leaf area, and individual height) and belowground traits (root average diameter, root dry matter content, specific root length, and maximum root depth) and the above-mentioned three demographic properties of regenerating seedlings were investigated for two dominantly regenerating tree species (*Abies sachalinensis* and *Acer mono*) in post-landslide forests. This monitoring was conducted in 2022 and 2023 in the "Artificial Landslide Experimental Sites (ALES)" established in the Nakagawa Experimental Forest of Hokkaido University. This study revealed that plant functional traits (small leaf area and deep roots), which were important for conservative resource use, supported seedling recruitment and growth. Meanwhile, the recruitment was also supported by drought-tolerant traits, such as high leaf dry matter content and high root dry matter content. On the other hand, there were no significant relationships between mortality and any of the plant functional traits measured in this study, which indicates that the mortality of regenerating trees after landslide is determined stochastically. Together, the results of Chapter 3 suggest that, depending on the demographic parameter, the determinant of regeneration is different in post-landslide forests, and it is necessary to integrate often-overlooked root traits to understand the important drivers of tree regeneration after landslides.

In Chapter 4, I conducted an artificial extreme-precipitation experiment for the seedlings of seven tree species planted in ALES. Characterizing species' responses to extreme precipitation is essential for understanding stress tolerance and resource use strategies and consequently the performance of trees under future climate change. Specifically, this study aimed to figure out how extreme precipitation influences the biomass of seedlings planted after landslides and whether species-specific plastic responses of seedling biomass to extreme precipitation were associated with the changes in functional traits. In the experiment, I used an artificial precipitation device and supplied water experimentally to seedlings in post-landslide forests (precipitation intensity: 50 mm per hour, duration: one hour, frequency: once per year at the end of July in both 2022 and 2023) to mimic the expected increase of the frequency of extreme precipitation. My study revealed that extreme precipitation increased the fine root biomass of *Ulmus davidiana*, and the increased fine root biomass was linked to the enhancement of whole-plant biomass of the seedlings of *Ulmus davidiana.* Because the increase in fine root biomass can be beneficial for the seedling performance in the harsh environment of post-landslide forests, planting *Ulmus davidiana* seedlings can be useful for the efficient restoration of post-landslide forests. In other words, my results suggest that tree species selection for the active restoration through tree planting in post-landslide forests should consider species that can plastically change their fine root biomass under increased water availability.

Finally, from the three studies, the relationships between functional traits and tree establishment after landslides in cool-temperate forests were discussed, and recommendations for forest restoration after landslides were provided. The main conclusions of my study were as follows: 1) the tree seedlings of species with higher fine root biomass exhibited better slope restoration after landslides because of their higher fine root Tr. 2) the tree species that plastically increase fine root biomass in response to extreme precipitation in post-landslide can increase whole-plant biomass of the seedlings. 3) successful seedling establishment with higher growth and recruitment after landslides tends to rely on conservative resource acquisition and drought tolerance functional traits. The findings of this thesis can provide essential knowledge for efficient restoration practices after landslides in cool temperate forests.