CHAPTER 1: General introduction

In Chapter 1, I introduce the relationship between soil carbon flow and climate warming. I review previous studies, which suggested that the responses of soil respiration and soil microbial communities to future climate change may vary widely across forest types.

Evergreen broad-leaved forest is the main natural vegetation type in the warm temperate zone of Japan. The potential land area of this forest type covers the western half of the Japanese Archipelago. Evergreen broad-leaved forest has a much higher carbon cycling rate than forests in cool climates, such as cool-temperate and boreal forests. However, few data are available on the potential impact of climate change on evergreen broad-leaved forests.

The objective of this study is to elucidate the effect of climate warming on the soil respiration and microbial community (heterotrophic and rhizospheric) in the evergreen broad-leaved forest of the warm temperate zone of Japan.
CHAPTER 2: Impacts of elevated CO₂ and temperature on soil respiration in warm-temperate evergreen *Quercus glauca* stands: an open-top chamber experiment

In this chapter, I describe an open-top chamber experiment that was conducted for 3 years to examine the effects of elevated CO₂ and temperature on soil respiration in experimental stands of *Quercus glauca*, an evergreen tree species common in the warm-temperate zone of Japan. Seedlings of *Q. glauca* were planted in open-top chambers and treated with ambient and elevated (ambient × 1.4, ambient × 1.8) CO₂ concentrations and ambient and elevated (+3 °C) air temperatures.

Elevated CO₂ significantly increased the total soil respiration rate (*P* < 0.001) and the soil respiration rate at 15 °C (*R*₁₅) (*P* < 0.05) but had no significant effect on the temperature-response coefficient *Q*₁₀. Although temperature significantly affected the total soil respiration rate (*P* < 0.05), neither the *R*₁₅ nor the *Q*₁₀ of total soil respiration was affected significantly by the air temperature increase. However, the *Q*₁₀ of heterotrophic respiration was (*P* < 0.01) significantly affected by elevated temperature. The annual soil respiration rate, estimated from *R*₁₅, *Q*₁₀, and soil temperature data, tended to increase with elevated CO₂ concentration. These results suggest that the soil respiration rate in Japanese broad-leaved forests dominated by *Q. glauca* is sensitive to elevated CO₂ and is likely to increase under future climatic conditions.
CHAPTER 3: Effects of experimental warming on the soil heterotrophic microbial community in a warm temperate evergreen broad-leaved forest: a three-year field experiment

The experiments described in Chapter 2 revealed that elevated temperature caused a significant change in the temperature sensitivity ($Q_{10}$) of heterotrophic respiration, which might have been caused by a change in the structure of the microbial community.

To elucidate the effect of climate warming on the soil heterotrophic microbial community in evergreen broad-leaved forests in the warm temperate zone, a soil warming experiment was conducted in a natural secondary forest in Higashi-Hiroshima in western Japan. Ten trench plots (1 m × 1 m) with barriers to prevent root regrowth were established in the forest. The plots were divided into warming and control treatments. Infrared heaters were used to increase the soil temperature of the warming plots by about 3 °C for 3 years. Phospholipid fatty acid (PLFA) analysis was used to examine the composition of the soil heterotrophic microbial community. There were no significant differences in the total content of PLFAs (TotPLFAs) and fungal PLFAs (FungPLFAs) between the warming and control plots. However, warming caused an increase in bacterial PLFAs (BactPLFAs), resulting in a lower ratio of FungPLFAs to BactPLFAs (F/B ratio) in the warming plots. In addition, PLFAs characteristic of Gram-negative bacteria increased in the warming plots. These results indicate that the soil heterotrophic microbial community in this evergreen broad-leaved forest is sensitive to climate warming.
CHAPTER 4: Effects of experimental warming on the rhizospheric soil microbial community associated with Quercus glauca seedlings

The rhizosphere is generally defined as the narrow zone of soil directly adjacent to, and affected by, plant roots. Rhizodeposition is an important source of carbon for microbes in the rhizosphere. In order to elucidate the effects of climate warming on the rhizospheric soil microbial community of Q. glauca, I conducted an incubation warming experiment in the laboratory. Three incubators were used to create different temperature conditions (15, 18, and 21 °C), and 40 Q. glauca seedlings growing in mesh bags (to separate rhizospheric soil from the bulk soil) were placed in each incubator. After 3 months, PLFA analysis was conducted to examine changes in the rhizospheric microbial community.

There were no significant differences in TotPLFAs in rhizospheric soil between the warming and control treatments. However, the FungPLFA contents in the warming treatments (18 and 21 °C) were significantly higher than that in the control (P < 0.05). These results indicate that the soil rhizospheric microbial community associated with Q. glauca seedlings is sensitive to climate warming.

CHAPTER 5: General discussion and conclusions

As described in Chapter 2, total soil respiration was significantly increased by elevated CO₂ and temperature. Although the effect on the heterotrophic respiration rate was not significant, the increased root respiration rate due to
elevated CO₂ and temperature is an important mechanism by which climate change will affect the ecosystem carbon cycle of evergreen broad-leaved forests in the warm temperate zone. In addition, the temperature sensitivity of heterotrophic respiration was changed by elevated temperature, which may have been caused by alteration of the microbial community structure. The experiments described in chapters 3 and 4 suggest that predicted climate warming will alter the soil microbial community in the bulk soil and the rhizosphere of this type of forest. Although many questions remain, including the possible increase in productivity that could result from elevated CO₂ and temperature, these results and those of previous studies indicate that the soil respiration and microbial community in evergreen broad-leaved forests of the warm temperate zone may be significantly affected by climate change.