Fine root dynamics and their contribution to carbon fixation in temperate forests of Japan and Korea

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ABSTRACT

Understanding patterns of carbon dynamics in terrestrial forest ecosystems is important in the matter of climate change because carbon fluxes between forest ecosystems and the atmosphere are closely related to changing atmospheric concentration of carbon dioxide. Also, forest ecosystems are major carbon sink on land, with tree roots and aboveground vegetation taking an important role in carbon and nutrient dynamics. The amount of carbon fixed by forests is indicated by the important index describing carbon budget of ecosystems, which is net primary production (NPP). NPP is an important index for evaluating the processes of carbon cycling in forest ecosystems. It is necessary to estimate NPP more accurately; however, in most studies on forest productivity, belowground fine root production has been ignored because of the difficulty of its estimation even though fine root production may account for up to 50 % of total NPP. Fine roots, primarily have an important role of resource acquisition such as soil nutrient and water, indicating an essential component for plant. Also, fine roots provide organic matter into a soil as a plant litter with high turnover cycles. Therefore, investigating fine root production and growth dynamics is important for our broad understanding of ecosystem carbon dynamics.

I investigated patterns and quantities of fine root mass and production and estimated NPP in temperate deciduous and coniferous forests of Japan and Korea. I used the ingrowth core and sequential soil core methods to investigate fine root dynamics. The estimates of fine root production were calculated using the simplified decision matrix and the continuous inflow estimate method. NPP was calculated based on the sum of changes in biomass of aboveground stems, branches, and coarse roots as well as annual litterfall mass and fine root production. The proportion of fine root or belowground total production to total NPP was estimated across stands. Moreover, the stand and environmental factors in relation to fine root production were investigated.

In chapter 2, I investigated litterfall and fine root biomass and production in five deciduous and four coniferous forests at the Gwangneung Experimental Forest in Korea. Annual litterfall production was not significantly different between the years. Annual fine root production was significantly higher in 2012 than in 2011. Annual litterfall production was significantly different among the stands, while fine root production did not statistically differ among the stands. Fine root production was positively related with NPP suggesting their greater carbon allocation to belowground in more productive forests.

In chapter 3, I estimated NPP using more accurate annual fine root production values, investigated fine root dynamics, and further investigated the relationships between above– and belowground organs in konara oak (*Quercus serrata*) and hinoki cypress (*Chamaecyparis obtusa*) forests at the Ryukoku Forest in Japan. The sum of aboveground litterfall and fine root production accounted for high proportion of the total NPP, confirming the significance of above- and belowground litter for the forest NPP as a source of detritus for the decomposer system. Fine root bio- and necromass were significantly different between forest types, sampling times, and root diameter classes. However, the seasonal patterns of fine root production did not differ among forest types, seasons, and root diameter classes. I found a possible relationship between above- and belowground production and fine root production was marginally high in productive forests.

In chapter 4, I investigated fine root dynamics and the relationships of fine root production with growth parameters as well as environmental factors using different root measurement methods in temperate broadleaved forests of Japan and Korea. The estimates of fine root production, mortality, decomposition and turnover were different by root measurement methods as well as calculation methods. The combination of the sequential soil core method and the decision matrix yielded higher production and lower turnover than the ingrowth core method with the continuous inflow estimate method. Fine root production was positively correlated with NPP, suggesting that high belowground carbon allocation in forests with high productivity. Air or soil temperature had an effect on fine root production or mortality and the relationship was different by applied methods and root diameter classes.

In the present study, the mass and production of fine roots varied among stands and years, and different methods of measurement and calculation yielded various estimates, resulting in changing the relationship between productivity parameters and environmental factors. Seasonal patterns of fine root production, mortality, and decomposition were more complicated than I expected. Several reasons can be propounded for rare significant relationships between fine root dynamics (production or turnover rate) and stand/environmental factors, such as large variation of fine root growth parameters (mass and production) and small sample size. It has been known that fine roots have inherent high temporal and spatial variation; therefore, it is necessary to increase sample size for estimating the realistic mean values of fine root mass and production at the stand level. However, increasing sample size is difficult and has a limit to the number of samples due to the high labor-intensive and time-consuming requirements of the techniques. Therefore, further study should consider and honestly clarify about this possibility and the present study point out the need to conduct more studies of fine root dynamics. There are still uncertainties about belowground ecology; however, I hope that the present study contributed to improve our understanding of carbon dynamics in forest ecosystems.