6 Limitation by an Insufficient Carbon Assimilation and Allocation

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6.1 Introduction

Carbon compounds are the currency that plants accumulate, store, and use to build their structure and maintain their physiological processes (Waring and Schlesinger 1985). Trees differ from other plants with respect to carbon investments in productive tissues and support structures. Most of the biomass of a tree is accumulated in woody tissues that do not photosynthesize but support the foliage and the fine roots (Friend et al. 1994; Gower et al. 1995).

Costs for maintaining these supporting and conducting tissues are high in trees when compared to dwarf shrubs and herbaceous plants with their more favourable leaf mass ratio, i.e. the dry matter of leaves in % of total plant mass (Boysen-Jensen 1932; Ellenberg 1975; Stevens and Fox 1991; Slatyer and Noble 1992; Körner 1994, 2003a; Cairns 1998; Cairns and Malanson 1998).

Thus, beside carbon gain, carbon allocation might be of equal importance in determining the upper physiological limit of trees (Bernoulli and Körner 1999). As both processes interact (Waring and Schlesinger 1985), we briefly review the carbon cycle of a tree (Fig. 6.1).

Carbon begins to cycle when the tree assimilates atmospheric CO₂ through photosynthesis into reduced sugars. Canopy photosynthesis is determined by net photosynthetic activity and the total amount of the photosynthetic active leaf surface area or leaf mass of the foliage and is integrated over selected daily or seasonal time periods.
Fig. 6.1. Major components of the carbon balance of a tree including photosynthesis, autotrophic respiration (solid arrows), partitioning, and allocation into various components, losses of organic matter (dotted arrows), and associated heterotrophic respiration.

The maintenance of existing cells as well as the growth of new cells requires energy, and a large portion of the carbon fixed by photosynthesis is lost via autotrophic respiration. Dry matter production, therefore, results from the balance between total canopy photosynthesis and the amount of carbon lost via autotrophic respiration. The remaining carbon can be allocated to various components and can be utilized for light capture (foliage), support (branches, stem, coarse roots), water and nutrient uptake (fine roots), reproduction (seeds and fruiting structure), and temporary storage of carbohydrates.

Losses of above ground organic matter due to dieback and shedding as well as fine-root turnover are the main contributors to litter, finally leading to an accumulation of soil humus, representing an important long term carbon storage pool in cold temperate forest ecosystems. Soil organic mat-