Nutrient supply of forest soils in relation to management and site history

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Abstract

Internal and external factors like forest management practices and atmospheric deposition may have large influences on the nutrient supply of forest soils. Examples are given for the effects of tree species, harvesting, site history, changes of species and specific soil conditions, nitrogen deposition, and forest growth dynamics. It is concluded from these examples that all of these factors may contribute to soil acidification in forest ecosystems under humid temperate climatic conditions.

Introduction

The nutrient supply of forest soils is influenced by a multitude of factors, both biotic and abiotic, internal and external, natural and anthropogenic, long-term and short-term, historic and recent (Fig. 1). The influences of site management were mainly the change of tree species, litter raking, grazing, and, most importantly, harvesting. These factors were, and partly still are, relevant for long periods in different intensities and with different geographical distribution. In addition more recently other anthropogenic influences are discussed on a wide scale. Phenomena like acid deposition, elevated N-input and atmospheric CO2 concentrations were revealed only during the last decades, but were found to largely influence the nutrient and health status of many forests. Furthermore, the widespread forest fertilization is new, at least in central Europe.

The factors mentioned above influence the nutrient supply either through a depletion of nutrients in the soil (enhanced growth and nutrient immobilisation, nutrient export from the site, reduced nutrient availability through humus degradation, elevated leaching losses of nutrients) or through an increase of nutrients in the soil ecosystem (nutrient input via deposition, fertilization). Acid and elevated N deposition into forest ecosystems can result in a reduction of soil alkalinity that may reduce the supply of nutrients such as Mg2+, Ca2+ and K+. In this context the reduction of base saturation represents soil acidification without a change of soil pH. A loading with strong acids will cause a decrease of base saturation and an accumulation of stronger acids if the rate of externally and internally generated acids exceeds the rate of proton consumption. It is frequently assumed - without being actually proven - that the rate of proton consumption related to silicate weathering (mobilisation of alkaline cations) is overcompensated by the proton production associated with the increment growth of - at least - commercial forests.

Following some effects of site management and site history with respect to the nutrient supply of forest soils are presented (cf. Huetttl, 1993).

Effect of tree species

Holstener-Joergensen et al. (1988) investigated the influence of 12 tree species on the chemical status of the soil. They hypothesized that plant nutrients includ-
ing cations (particularly Ca\(^{2+}\) and Mg\(^{2+}\)) assimilated in the biomass are largely immobilised. If these cations are not substituted in the soil through supply by weathering or through supply from outside, the soil nutrient pool will be depleted in a continuous process with a lasting effect if the biomass is exported by harvesting, litter raking or grazing. This process would also lead to an equivalent acidification of the soil. Since the basal area increment is a measure of tree growth on a specific area and thereby of the accumulation of biomass in this area, parameters of acidification and base cation loss in the soil must be expected to occur as a function of the increment growth of the trees.

Typic Danish forest sites were selected with soils from various geological origin as well as different climatic conditions. 20 years after planting of 12 tree species, soil samples were taken from the upper 5 cm of the mineral soil. Even though the well-known species specific dry matter production, differences between various tree species in their nutrient assimilation and other factors were not adjusted in this investigation, soil acidification clearly depended on the average basal area increment of the trees reflecting cation immobilisation by the stand.

Another example comes from a study of Binkley and Valentine (1991) at the Saltonstall Watershed in Connecticut, USA. In 1938 replicated plantations with green ash (*Fraxinus pennsylvanica*), white pine (*Pinus strobus*), and Norway spruce (*Picea abies*) were carried out on an acid brown earth. These plantations were reinvestigated 50 years later.

In the top 5 cm of the soil, pH was found to be highest under ash and lowest under spruce (Fig. 2). Significant differences were also analyzed with regard to the distribution of plant available cation species. There was no difference in the sum of cations, but ash plots had more than twice the exchangeable amount of Ca\(^{2+}\) and Mg\(^{2+}\) as compared to the spruce plots (Fig. 3). Furthermore, large differences were analyzed in Al\(^{3+}\) contents. The sum of Ca\(^{2+}\) + Mg\(^{2+}\) + K\(^{+}\) in the topsoil (0–15 cm) was by 16 kmol ha\(^{-1}\) greater under ash than under spruce. Like in European forest decline (cf. Huettl, 1991) Mg deficiency and an unbalanced Mg/Al ratio in the soil solution was detected under spruce. In spruce litter large Al and low Mg contents