soil systems

Editorial

Forest Soils: Functions, Threats, Management

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The specific characteristic of forest soils is their long-term development under a more-or-less continuous vegetation cover. With deeper-reaching rooting zones and high activity of microbes, soil fauna and plant roots have high humus contents and above-average high porosity and continuity of the soil pore system compared with other land use types [1,2]. Contamination with pesticides is comparably low in forest soils, since forests are nature-near ecosystems [3], and the high demand from trees and soil biota for essential nutrients such as phosphorous and nitrogen leads to low leaching rates of those elements [4]. Thus, forests and forest soils are sources of predominantly pure drinking water [5].

However, some of the functions of forest soils are endangered under the influence of environmental and climate changes, and because of inadequate forest-management measures. The high crown surface of forests combs out acids and nitrogen from air pollution, which leads to severe soil acidification in parts of Central Europe and other industrialized regions [6]. Additionally, the use of heavy forest machinery can cause soil compaction, leading to deficits in soil aeration which can restrict the rooting space for forest trees in the uppermost soil layers [7–10]. Moreover, C-sequestration and greenhouse gas balances in forest soils are highly relevant topics which are also represented in the present Special Issue.

This Special Issue addresses the specific functions of forest soils, the processes which endanger the integrity of these functions, and potential management approaches to counteract the processes which threaten soil functions. This Special Issue comprises one review article [11] and nine research articles [12–20]. The order of the research articles starts with process-oriented studies on the specific functions and threats of forest soils [12–17] and ends with management-oriented studies deriving from and evaluating management approaches which can maintain or recover specific forest soil functions [18–20].

The review article was conceptualized as the leading article of the Special Issue, giving a comprehensive overview on the structures and processes differentiating forest soils from soils of other land use types and defining their specific value. From 208 relevant articles, this literature review revealed that forest soils provide a predominantly differentiated soil structure—the basis for their high ecological functionality. The review also revealed that active management measures must be set in motion to preserve the vulnerable functional structures of forest soils under fast-changing environmental conditions [11].

Schäffer examined 11 forest sites in the federal state of Baden-Wuerttemberg (Germany) with time intervals of 6–37 years between soil compaction from heavy forest machines and observation [12]. Fine root distribution, macroporosity, and apparent gas diffusion coefficients were used to characterize the status of recovery from former soil compaction. He observed a high persistence of damages below 10 cm soil depth, stating that "time spans up to almost four decades are not sufficient for the restoration of soil functionality in compacted silt loam soils". This contribution is an example of management-related threats for forest soil functions.

Takahashi et al. contributed a meta-analysis on the storage and stoichiometry of nutrients—nitrogen, phosphorus, potassium, calcium, and magnesium—in the humus layer of coniferous forests in Japan with different regional climate and soil characteristics [13]. In "cedar and cypress plantations on fertile sites, the forest floor stored low N and P with high C:N and C:P ratios, suggesting that the forest floor plays there only a minor role as a nutrient reservoir. Subalpine coniferous forests and fir plantations in cool climates had large N and P storage with low C:N and C:P ratios in the forest floor”. Thus, the relevance of the storage of essential nutrients in the humus layer for a consistent stand nutrition, even under the impact of climate change, was evaluated.

Rwibasira et al. contributed a study from Rwanda on the long-term effects of different tree species on soil functions characterized by the proxy entities soil acidity, soil organic matter, and exchangeable base cations [14]. They found that Eucalyptus species caused soil acidification, whereas soil-exchangeable cations and pH were higher under native species. In “selecting forest trees, priority should be given to the species which do not negatively alter chemical soil quality”.

The study of Zhuang et al. deals with the “home-field advantage of litter decomposition”, indicating that litter decomposition is enhanced through specifically adapted decomposer communities in areas where tree species are established—the “home-field”. The context of the study is the silvicultural strategy, which shifts tree species composition from mono-cultural spruce stands to nature-near beech stands in the Eifel national park (West Germany). In a “litter transplant experiment” in stands of Norway spruce and European beech and adjacent clear-cuts, the authors found that litter of “spruce decomposed faster in spruce forest while beech-litter decomposed faster in clear-cut, indicating the occurrence of a home-field decomposition advantage at forest” stands for spruce “and clear-cut” for beech. They concluded that “clearcutting modifies the litter-field affinity and helps promote the establishment or regeneration of European beech in this and similar forest mountain upland areas” [15].

Melnichuk et al. studied the introduction of invasive earthworms, finding that it initiates physical and chemical alterations in previously earthworm-free forest soils, which “triggers an ecological cascade”, leading to an “apparent shift in the herbaceous ground vegetation” [16]. An interesting result was that Arisaema triphyllum resisted earthworm invasion—because this species was able “to produce insoluble oxalate as an herbivory deterrent, in the presence of earthworms”.

The contribution of Jandl et al. aimed to quantify the effect of long-term environmental change on soil acidification, nitrogen enrichment, and the loss of soil organic carbon due to climate change. They evaluated data from two soil survey campaigns comprising a time period of 20 years [17]. They found changes in the stocks of soil organic carbon, soil nitrogen, and soil pH. However, the changes were inconsistent. The authors conclude that “changes in the evaluated soil chemical properties are mainly driven by forest management activities”, and that climate change effects have not changed the soil organic carbon stock until now in an unambiguous way.

Since recent studies investigating the plant-mediated alleviation of soil compaction with black alder showed promising results, Warlo et al. used the “characteristics of soil structure and greenhouse gas fluxes to measure soil recovery and GHG fluxes on machine tracks with and without black alders in North-East Switzerland”. Unexpectedly, they found that, ten years after machine impact, “alder had no beneficial impact on soil physical parameters”. Moreover, the symbiotic nitrogen fixation by alder led to elevated cumulative N_2O emission, and thus has “the potential to deteriorate the GHG balance of the investigated forest stand” [18].

Ahrends et al. studied the possible recovery from acid deposition as depending on tree species, evaluating data from limed and unlimed plots of 21 long-term and extensively instrumented ecosystem studies in Lower Saxony, Germany [19]. The data allowed for trend analyses of the acid-base status over a period of 30–50 years. The recovery, if indicated by an increase in soil pH and base saturation, of soils from limed plots and “plots with deciduous trees appears to have occurred faster than in coniferous forest stands”. As the recovery from soil acidification is slow and the acid-base status still shows considerable soil acidification, “mitigation measures such as forest liming still appear to be necessary for accelerating the regeneration process”.

The study on "merits and limitations of element balances as a forest planning tool for harvest intensities and sustainable nutrient management" by Ahrends et al. "provides valuable information for practitioners and environmental policy makers to enable spatiotemporal adaptive ecosystem management on the reliable and quality-assured basis of monitoring data" [20]. "The effects of conventional stem harvesting, stem harvesting without bark, and whole-tree harvesting on Ca, Mg and K balances were studied. The nutrient balances were calculated using regular forest monitoring data supplemented by additional data from scientific projects. Effective mitigation management strategies and options are discussed and calculations for the compensation of the potential depletion of nutrients in the soil are presented".

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