Soil organic matter dynamics in virgin and secondary forests of northeastern China

Diploma thesis by
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7 Summary and outlook

The objective of this study was to examine the impacts of forest clearing (once or twice) and subsequent natural forest recovery on soil organic matter dynamics in northeastern China. Soil organic matter is of capital importance to a soil’s fertility and resistance to degradation. Moreover, in most terrestrial ecosystems, it represents the major storage of carbon and nitrogen, which can contribute to global warming when released to the atmosphere in form of greenhouse gases. Therefore, the maintenance of soil organic matter stocks is of special ecological interest. The study was performed using the approach of “space-for-time substitution”, i.e. the examination of chronosequences. Therefore, two experimental areas, located in the province of Heilongjiang, were selected. One area, referred to as “Mao’ershan”, was located in the Mao’ershan National Forest Park where three types of land use were studied, forests that were cut once, 70 years ago, and forests that were cut twice, either 70 and 30 or 70 and 50 years ago. The other area, referred to as “Liangshui”, was located in the National Nature Reserve of Liangshui, where four kinds of forest were studied, namely virgin forests and forests that were cut 30, 50, or 70 years ago, respectively. The variables studied were the humus form, mineral soil pH, as well as contents and stocks of mineral nitrogen, water-soluble organic carbon, and total carbon and nitrogen.

The results suggest that clearing caused the humus form to change from biologically less active humus forms (moder, mull-like moder) to biologically more active humus forms (F-mull) in the first 30 years after clearing. Concurrently, the carbon and nitrogen stocks of forest floors and the mineral soil decreased. In Liangshui, this was also accompanied by an increase in pH. An observed decrease in C/N ratios of the forest floors, 30 years after clearing, is in line with the observed humus form changes and indicates that the vegetation established after clearing produced a more easily decomposable litter as compared to the vegetation that prevailed before the clear-cut. In Liangshui, a shift from a conifer-dominated forest to a forest dominated by broadleaf trees was probably the major factor. A rise in decomposition rates is also supported by increased levels of water-soluble organic carbon, 30 years after the clear-cut. A few decades later, the trend apparently reversed. Forest floors changed towards biological less active humus forms and the stocks of carbon and nitrogen increased to a level even higher than the original one, 50 and 70 years after clearing in Mao’ershan and Liangshui,
respectively. A possible explanation is the high uptake of nutrients by quickly growing plants leading to the depletion of the soil nutrient stock. This may have reduced the biological activity and hence decreased decomposition rates. A concurrent decline in water-soluble organic carbon pools also indicate decreased mineralization. A factor that contributed to the accumulation of soil organic matter could be a delayed adaptation of the soil’s destruent community to new conditions, mainly imposed by a shift in the species composition. The increase in total carbon and nitrogen stocks could mainly be attributed to increased thicknesses of $A_h$ horizons, possibly indicating that the vegetation recovering after clear-cut allocated more organic matter in deeper soil layers where decomposition rates are low.

Total carbon and nitrogen stocks as represented by the combined stocks of the forest floor and the $A_h$ horizon were largely dominated by the $A_h$ horizon. The small contributions of the forest floors to total stocks suggest that a high biological activity effectively leads to the incorporation of organic matter into the mineral soil. On the other hand, the huge mineral soil stock suggests that decomposition is restricted. Conditions that favor biological activity in the summer (sufficient water, moderate temperatures) may promote the incorporation of organic matter into the soil whereas low temperatures (frost) in the winter inhibit its decomposition. The fact that the amounts of carbon and nitrogen stored in forest floors and mineral soils increased after clearing to a level higher than that observed in the original forests, may be a sign of increasing senescence of trees as the forests grow old. The death of trees leads to increased incidence of light onto the forest floor, and hence warming-up of the soil, as well as the return of nutrients to the decomposer system, both of which promote decomposition.

It may be hypothesized that clearing of virgin forests or secondary forests in northeastern China causes a decline in soil organic matter stocks that lasts for a few decades. After 50–70 years, however, natural recovery of forests has restored or even led to an increase in soil organic matter stocks. The differences between Liangshui and Mao’ershlan with respect to soil organic matter dynamics observed after forest clearing may indicate that soil organic matter stocks that have been build up after a first forest clearing event are less resistant to decomposition and thus faster depleted after a second clearing event. However, this effect could have also been a result of differences between the two areas that were not associated with the clearing events (vegetation, climate).

Changes in mineral nitrogen pools after clearing did not show a consistent trend. In Liangshui, they appeared to be increased after clearing whereas in Mao’ershlan the opposite was observed.
Considering that nitrate accounted for more than half of the total mineral nitrogen pool, that C/N ratios of forest floors (20–26) and mineral soils (11–13) were comparably low, and that increased decomposition rates during the summer are accompanied by concentrated precipitation, nitrate leaching is likely to occur during the summer. However, an examination of actual nitrate levels in the groundwater is required to draw a conclusion.

Each type of land use studied, i.e. the treatment (e.g. virgin forest), was represented by three replicate sites. Compared to the great variabilities observed in the target variables (e.g. total carbon and nitrogen stocks), most differences between treatments were very small. Consequently, statistical analyses seldom revealed significant results. In addition, the use of the chronosequence approach is only justified if the comparability of the treatments forming the sequence is ensured, so that differences between treatments can almost certainly be attributed to the factor studied (e.g. clear-cut, stand age). Due to the complexity of multi-species forest ecosystems, it is difficult to find comparable sites. Especially the forest floor masses have been proved to be subject to great variabilities. Future research should preferably be based on a greater number of replicate sites.

As carbon and nitrogen dynamics in forest soils crucially depend on the prevailing vegetation and its properties (chemical composition of the litter, strategy concerning the allocation of assimilates belowground), a more comprehensive knowledge about the present plant community is desirable. Further investigations could include the calculation of mass balances concerning carbon and nitrogen, based on the determination of in- and outputs. Model simulations can possibly be very helpful in determining the driving forces in changes of carbon and nitrogen stocks.