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Soil carbon dynamics in oak and Norway spruce afforestation chronosequences on former cropland: heterotrophic respiration and decomposability of organic matter

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Previous studies of environmental impact of cropland afforestation in a long-term experiment at Vestskoven, Denmark focused on changes in SOC stocks. Chronosequence and repeated sampling approaches revealed that soils initially lost C but started to gain C after about three decades. Soil carbon stocks represent the balance between litter input and heterotrophic respiration, and we hypothesized that heterotrophic respiration and in particular the decomposability of the organic matter would decrease with time after afforestation of cropland. The objective of this study was to assess the heterotrophic respiration (RH) and decomposability of SOC, i.e. the rate of respiration relative to content of SOM (RH/SOM), along chronosequences of Norway spruce (Picea abies (Karst.) L.) and oak (Quercus robur L.). The chronosequences included 15 stands aged 4-44 years and were supplemented by a permanent pasture (36 years), a cropland plot and a 200-year-old oak-dominated plantation for reference. Samples from top mineral soil (0-5 and 5-15 cm layers) were sampled by auger and incubated in a respirometer (Respicond VII) for three weeks at 15°C to assess potential RH and RH/SOM.

Heterotrophic respiration (RH) in the 0-5 cm layer increased with time since afforestation in stands of both tree species while there was no change in decomposability of SOC (RH/SOM) with time or between tree species. In 5-15 cm, RH and RH/SOM were both unchanged after afforestation, but oak stands had significantly higher RH than Norway spruce in this layer and RH/SOM also tended to be higher. Cropland RH was low and comparable to that of the 4-year-old oak stand, whereas the 200-year-old plantation and the pasture generally had higher or similar RH rates compared to the older chronosequence stands. RH/SOM was comparable in cropland and afforested stands whereas RH/SOM was lower in the 200-year-old afforested stand. The increase in RH with age occurred concurrently with increases in SOC stock and C/N ratio in addition to a significant decrease in soil pH. These changes were most pronounced in the 0-5 cm layer.

We conclude that the respiration flux of C from mineral soil increased with time since afforestation in a 45-year perspective, whereas the decomposability of SOC was unchanged. Tree species did not affect SOC dynamics to any large extent, but respiration fluxes were lower in 5-15 cm under Norway spruce than oak, and SOC decomposability tended to be lower under spruce in the same layer. This suggests that RH fluxes along the chronosequence are controlled by the amount of SOC in soils rather than by changed decomposability of SOC four decades after afforestation of former cropland. The results also indicate that initial losses and later gains in SOC stocks after afforestation would be more driven by temporal changes in litter input than by decreasing SOC decomposability in mineral soil. However, RH/SOM was lower in the 200-year-old oak stand on former cropland suggesting that SOC may become more stable in the long-term after afforestation.