Geophysical Research Abstracts
Vol. 15, EGU2013-11356, 2013
EGU General Assembly 2013

A meta-analysis of soil carbon stock change following afforestation in Northern Europe.

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Studies of soil organic carbon (SOC) stock change after afforestation have shown different patterns in terms of magnitude, direction (gain, loss or no change) and duration. Due to data shortage at regional or national scales, global datasets have commonly been evaluated by meta-analysis to address the effects of land-use changes on SOCs. Few syntheses on afforestation effects have been conducted at more constrained spatial scales where the influence of site-specific factors is smaller. Here, we present a meta-analysis of relative change in SOC within the Northern European region (including 123 observations), which has not been well represented in previous syntheses. Effect sizes were determined by log response ratios (RR) for each control-afforested pair. The first objective was to quantify effects of afforestation on SOC stocks in forest floors and mineral soils (0-10 cm and 0-20/30 cm). We tested the influence of different former land use classes, such as croplands and grasslands, forest age and forest type on the estimated SOC stock changes. The second objective was to address the influence of study design. SOC stock estimates from control/afforested plots have an implicit spatial dependency according to the experimental approach used (e.g. paired site studies, chronosequences sharing a common control site and repeated sampling design), however, this has not been accounted for in meta-analyses of afforested soils. In addition, changes in SOC stocks (in 0-10 cm) were expressed on equivalent soil mass and equivalent soil volume to estimate possible differences in effect size originating from these two SOC accounting methods.

Preliminary results indicate an overall positive effect of afforestation on SOC accumulation with age, supported by the oldest age classes (>30 years). This effect was enhanced when the forest floor was included in the total SOC stock, in particular for coniferous forests, highlighting the importance of this layer in soil C sequestration. Afforestation on former grasslands had a negative (RR= -0.06, for both soil depths) non-significant ($p > 0.05$) effect on SOC stocks indicating limited change in SOC following this land-use change. In croplands, effects depended on the soil layer considered and were significantly positive (RR= 0.14, $p < 0.05$) in the 0-10 cm layer, while negative and non-significant (RR= -0.01, $p > 0.05$) in the 0-20/30 cm layer. This suggests that cropland to forest conversion may increase SOC stocks in top soils within a decadal time scale.
Not accounting for different study designs and their implicit spatial dependency resulted in an overestimation of the RR; however, there was no influence on the major trends. Lastly, effect sizes were underestimated if the meta-analysis was based on equivalent soil volume, since bulk densities of soil were generally lower in afforested plots.

Finally, we conclude that significant SOC sequestration in Northern Europe occurs after cropland to forest rather than grassland to forest conversion, and changes were small within 30 years after land-use change. Furthermore, accounting for spatial dependency from various study designs and for equivalent mass in datasets may influence the conclusions of meta-analyses.

Keywords: meta-analysis, land-use change, carbon stocks, soil, afforestation, Northern Europe.