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How much will afforestation of former cropland influence soil C stocks? A synthesis of paired sampling, chronosequence sampling and repeated sampling studies

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The need for documentation of land-use change effects on soil C is high on the agenda in most signatory countries to the Kyoto Protocol. Large land areas in Europe have experienced land-use change from cropland to forest since 1990 by direct afforestation as well as abandonment and regrowth of marginally productive cropland. Soil C dynamics following land-use change remain highly uncertain due to a limited number of available studies and due to influence of interacting factors such as land use history, soil type, and climate. Common approaches for estimation of potential soil C changes following land-use change are i) paired sampling of plots with a long legacy of different land uses, ii) chronosequence studies of land-use change, and lastly iii) repeated sampling of plots subject to changed land use. This paper will synthesize the quantitative effects of cropland afforestation on soil C sequestration based on all three approaches and will report on related work within Cost 639.

Paired plots of forest and cropland were used to study the general differences between soil C stocks in the two land uses. At 27 sites in Denmark distributed among different regions and soil types forest floor and mineral soil were sampled in and around soil pits. Soil C stocks were higher in forest than cropland (mean difference 22 Mg C ha-1 to 1 m depth). This difference was caused solely by the presence of a forest floor in forests; mineral soil C stocks were similar (108 vs. 109 Mg C ha-1) in the two land uses regardless of soil type and the soil layers considered.

The chronosequence approach was employed in the AFFOREST project for evaluation of C sequestration in biomass and soils following afforestation of cropland. Two oak (Quercus robur) and four Norway spruce (Picea abies) afforestation chronosequences (age range 1 to 90 years) were studied in Denmark, Sweden and the Netherlands. Forest floor and mineral soil (0-25 cm) C contents were as a minimum unchanged and in most cases there was net C sequestration (range 0-1.3 Mg C ha-1 yr-1). The allocation of sequestered soil C was quite different among chronosequences; forest floors consistently sequestered C (0.1-0.7 Mg C ha-1 yr-1) but there was no general pattern in mineral soil C sequestration.

While the paired sampling and the chronosequence approaches both may be confounded by site factors other than the land use, repeated sampling of plots best addresses the pure land-use change effect. Repeated sampling after 18 years was done in a systematic 7x7 km grid to address soil C changes in 15 cropland plots that were converted to forest (7-22 years since afforestation). Consistent with the other two approaches, detectable soil C changes were confined to the forest floor component; forest floor C sequestration rates were 0.24 Mg C ha-1 yr-1 while no changes were detected for mineral soils.

The three approaches to estimation of soil C sequestration indeed point to a common conclusion: The potential for soil C sequestration is mainly confined to the forest floor whereas notable C sequestration is less likely to occur in the mineral soil. However, more generalizable knowledge is badly needed for reporting of land-use change effects on mineral soil C pools. WG II of Cost 639 and the FP7 project GHG Europe is currently establishing a database of LUC studies. This database will be used to establish so-called Carbon Response Functions (CRF), i.e. simple models predicting the annual rate of change in soil C pools. These CRFs may serve as tools for syntheses of land-use change effects for Europe as well as for improved reporting of soil C dynamics following land-use change.