Modeling long-term soil organic carbon dynamics in forage-based crop rotations in Subarctic Sweden (62-63 ^{o}N)

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Key Words
Boreal zone, long-term experiments, agro-ecosystems, land use change, initial site characteristics.

Introduction
For carbon sequestration estimates it is necessary to evaluate effects of management practices on soil organic carbon (SOC) dynamics in a wide range of production systems and climatic zones. At higher latitudes with cold temperate climate, crop rotations dominated by forage are common and often highly productive – and the climate as well as the forage cropping systems favours large stocks of SOC. The objective of this study was to estimate and describe SOC stock dynamics in the arable topsoil layer (0 to 25 cm depth) for different 6-yr forage-based rotations using sampling data from three long-term field experiments in "Norrland", i.e., North Sweden.

Methods
The continuous forage rotation ('A'), received ca. 1 kg C/m^2 as cattle manure per year, and rotation 'B' had 4 years of forage and two years of annuals, receiving the same amount of manure. Rotation 'C' had 3 years of forage and received 0.7 kg C/m^2 of manure. Rotation 'D' had only annuals and no manure application. We used plant C allometric functions developed for forage crops together with *The Introductory C Balance Model* (ICBM; Andrén and Kätterer 1997; Andrén *et al.* 2007, 2008ab) to describe SOC dynamics for the continuous forage rotation ('A') without parameter tuning. Then we adapted the ICBM soil climate and decomposer activity parameter (r_e) to account for the major effects of increased tillage in rotations 'B' to 'D' (see e.g. Andrén *et al*. 2007; Bolinder *et al.* 2007). The r_e parameter usually is calculated from sub-parameters based on climate, soil type, crop type, intensity of cultivation etc. and in this case the effects of forage crops vs. annuals on cultivation intensity are of special interest – can cultivation effects in these extreme conditions be described following normal assumptions?

Results and discussion
At the site with the lowest, but still comparatively high, initial amount of SOC (8.2 kg C/m^2 in topsoil down to 25 cm), SOC stocks increased by 12 g C/m^2/yr over a 50-year period for the continuous forage rotation ('A'). At the same site, SOC stocks were more or less at steady-state in rotation 'B', receiving the same amount of manure. For rotation 'C' with more annuals and less forage and manure, SOC stocks decreased by 18 g C/m^2/yr, while the SOC stocks for rotation 'D' (no forage, no manure) decreased by 24 g C/m^2/yr. At the other two sites, with higher initial SOC stocks (12.8 and 14.3 g C/m^2), SOC stocks in all treatments decreased during a 30-year period, ranging from 11 to 168 g C/m^2/yr. The four-parameter model ICBM allowed us to describe SOC dynamics for the continuous forage rotation ('A') without parameter tuning: deviation between measured and predicted final SOC stocks were less than ± 5%. The adaption of parameters (yield/crop residue input, manure addition) that affected annual inputs and 'litter quality' explained a major part of the differences between treatments, and when we also took differences in cultivation into account we could satisfactorily describe all treatments. However, without separate measurements of cultivation effects ('How much carbon is actually lost due to cultivation effects only) we cannot separate cultivation effects from other components of r_e. To be able to actually refine and develop models we need more high-precision, unbiased field from adequately designed field experiment (see, e.g., Andrén *et al.* 2008).

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