



Carbon budget of Finnish croplands – Effects of land use change from natural forest to cropland



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ABSTRACT

The pool of soil organic carbon (SOC) in Finnish croplands has declined during recent decades according to nation-wide soil inventories, but reasons for this trend remain unclear. We studied the possible reasons using an approach based on the Yasso07 soil carbon model. We evaluated also the suitability of this approach for estimating the pool and changes of SOC in boreal croplands at the regional scale. The simulated SOC pool declined in each of the four study regions we divided the country into over the entire study period from 1900 to 2009. During the last 35 years, the mean estimate of the decrease rate varied from 0.29 to 0.36 Mg ha⁻¹ year⁻¹ among the regions. The mean estimate of the SOC pool in the croplands varied from 92 to 124 Mg ha⁻¹ at the end of the study period. In a sensitivity analysis, the estimates of the decrease rate slowed down by 25% or accelerated by 38% at most, whereas the pool estimates increased or decreased by 18% at most. According to our simulations and the sensitivity analysis, the SOC pool declined because croplands produced less litter than pre-cropland forests and this agricultural litter decomposed more rapidly. On the other hand, climate warming has not been a significant reason for the decline yet. Increasing carbon input to the cropland soil by applying organic manure and avoiding bare fallow are means to slow down the loss of SOC. The simulated estimates were similar to measurement-based ones available for comparison. We concluded that our approach was suitable for studying the reasons for the declining trend of SOC and the major uncertainties were caused by inexact input values.

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1. Introduction

Croplands can act as either sources or sinks of atmospheric carbon depending on environmental conditions and agricultural management practices (Lal, 2004). There is a growing concern about the negative effects of climate warming on the balance of soil organic carbon (SOC) in the croplands (Obersteiner et al., 2010). It is uncertain how land use changes and management practices will affect the SOC pools of croplands under changing climate. Agricultural management, such as selection of crops, crop rotation, fertilization and harvest intensity, is known to affect the carbon sink potential of the croplands because it determines the quantity and the composition of organic matter entering the soil (Paustian et al., 1997).

In croplands, like in all terrestrial ecosystems, the pool of SOC and changes in this pool over time are determined by the balance between carbon input as plant residues and organic amendments, and output resulting from decomposition, erosion and leaching. Previous land

use, agricultural management and climatic conditions all affect the cycle of SOC (Lal, 2004). A characteristic feature of croplands is that a considerable share, often 40 to 60%, of the annual net primary production (NPP) is harvested, which reduces the fraction ending up in soil as a dead organic matter (Hay, 1995). This is seen as a major reason for declining SOC pools observed in cropland soils (Leifeld, 2013).

Changes in the SOC pool of croplands can be quantified using repeated SOC inventories or modeling at regional or national scales. In Finland, the pool and changes of cropland SOC were recently estimated based on successive soil inventories between 1974 and 2009 (Heikkinen et al., 2013). According to these inventories, the SOC pool decreased at an average rate of 0.22 Mg ha⁻¹ year⁻¹ during this period. The authors could not explain reasons for this trend based on the soil inventories alone, and they suggested to study them using simulation models. Such models have been used elsewhere in Europe earlier (e.g. Gervois et al., 2008; Smith et al., 2007). These studies have revealed that changes in agricultural management, such as increased harvest intensity, a shift towards mineral fertilization and cultivation of annual crops, have been the main reasons for decreasing trends in the SOC pools of European croplands.

In this study, we used the Yasso07 soil carbon model (Tuomi et al., 2009, 2011a, 2011b) to analyze reasons for the decrease in the SOC

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pool of Finnish croplands. This model is already used to estimate the carbon budget of forest soil in the national greenhouse gas inventory of Finland (NIR, 2012). The model and its predecessor Yasso (Liski et al., 2005) have also been applied in various other studies to estimate, for example, the effects of climate change (Thum et al., 2011), land-use change (Karhu et al., 2011; Lu et al., 2013), forest management (Johnson et al., 2010) and bioenergy on the SOC pool (Liski et al., 2013; Repo et al., 2011, 2014a, 2014b). In addition, the validity of the Yasso07 model has been tested specifically at boreal cropland sites. These tests suggest that this model is suitable for estimating the effects of organic amendments (Karhu et al., 2012) and those of afforestation and deforestation (Karhu et al., 2011) on the SOC pool. However, the validity of a modeling approach based on the Yasso07 model at a larger regional scale remains to be tested.

The first objective of this study was to find out reasons for the decreasing trend in the SOC pool of Finnish croplands. The second objective was to evaluate the suitability of an approach based on the Yasso07 model for estimating the pool of SOC and changes in this pool in boreal croplands at a regional scale.

2. Materials and methods

2.1. General description of the study

Finnish croplands cover 2.2 million ha of land and are mainly located in the southern and western parts of the country (Fig. 1). We divided these croplands into four geographical regions (south, west, east and north) and simulated the SOC budget of the croplands in each region between 1900 and 2009 using the Yasso07 soil carbon model. We excluded organic croplands from this study since the model is applicable for mineral soils only. To test the validity of the simulation results, we compared them to measurements of the pools and the temporal trends of SOC. To study reasons for the observed decline in the SOC pool, we carried out a sensitivity analysis.

2.2. The Yasso07 model

The Yasso07 soil carbon model is based on three assumptions of litter decomposition. According to the first one, litter consists of four

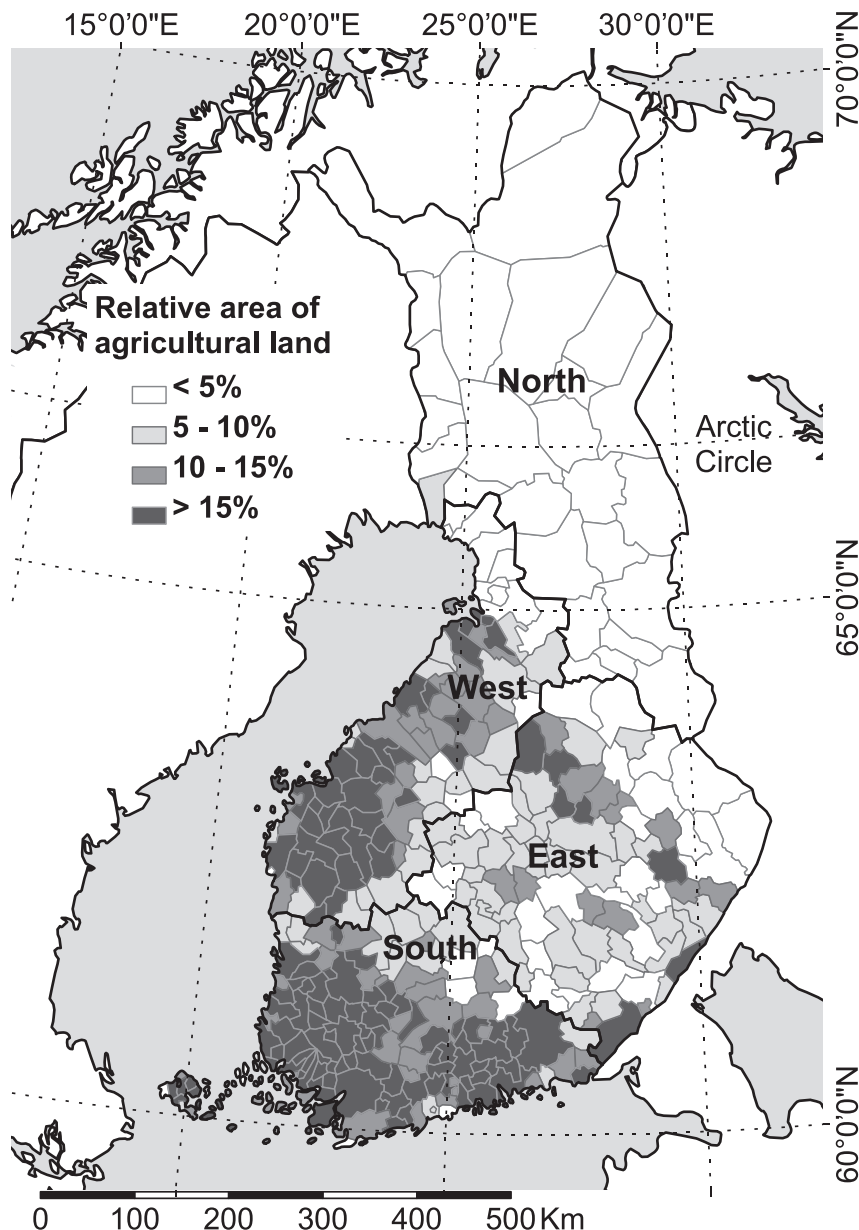


Fig. 1. The croplands in Finland and the study regions of this research.

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