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Volker Häring "Effects of Land Use Change on Soil Organic Carbon Dynamics in Northwest Vietnam", University of Hohenheim, 2013

Summary

Deforestation and subsequent crop cultivation is a widespread land use change which usually leads to a net decline in soil organic carbon (SOC) stocks, a decline in soil fertility and an increase in CO_2 emissions. However, to date, (1) the determination of SOC dynamics on erosion prone sites is challenging due to methodological shortcomings; (2) limited knowledge is available on the effect of soil texture and tillage on SOC dynamics; and (3) the effect of land use change from forest to maize on SOC dynamics has rarely been studied in Southeast Asia.

Thus, the aims of the present study were

(1) to develop a δ^{13}C based method (CIDE; Carbon Input, Decomposition and Erosion) to characterize SOC dynamics on erosion prone sites;

(2) to determine the effects of soil texture and tillage on SOC dynamics;

(3) to determine bulk soil erosion, decomposition, SOC erosion, and net maize derived SOC input after land use change from forest to maize.

Chronosequences covering up to 21 years of continuous maize cultivation after deforestation of primary forest were identified on three soil types (Cutanic Alisol [Chromic], Cutanic Luvisol, and Haplic Vertisol [Chromic]) in the Yen Chau district, NW Vietnam. Soils were sampled in 10 cm depth increments to 30 cm soil depth.

Key message 1: The newly developed CIDE approach determined SOC dynamics more reliable than a commonly applied δ^{13}C based mass balance approach

The assessment of SOC loss and input after land use change is largely based on comparisons between disturbed sites and an undisturbed reference site at fixed sampling depths (e.g. 0-10 cm). At erosion prone sites this comparison neglects the interactions between soil erosion, decomposition and SOC input and leads to two shortcomings. First, the SOC lost by soil erosion before sampling is not considered. Second, it is not known whether the SOC change between the two sites is caused by SOC loss and SOC input or by soil profile truncation due to soil erosion. To overcome these shortcomings, the CIDE approach considers (1) SOC contained in the topsoil which was removed before sampling the present topsoil, and (2) erosion induced exposition of the subsoil with different contents of SOC, δ^{13}C values and bulk density compared to the topsoil. The basic principle of the CIDE approach is that the depth of the reference SOC content,, δ^{13}C and bulk density is adjusted to correspond to the

sampled layer depth of a compared cultivated site. This depth adjustment considers the site specific soil erosion and bulk density change. Necessary input data include SOC content, $\delta^{13}C$ and bulk density of each site, fitted functions describing the distribution of these parameters with soil depth under an uncultivated reference site, and measurements or estimates of either soil erosion or decomposition at each site.

An uncertainty analysis showed that, from low erosion rates on (i.e. 3 t ha^{-1} a^{-1}), a commonly applied $\delta^{13}C$ based mass balance equation underestimated SOC loss (sum of erosion and decomposition) and overestimated real soe input. The misrepresentation was particularly high under conditions of high soil erosion rates, small changes in SOC content with depth, large changes in $\delta^{13}C$ with depth, and small changes in SOC stocks or $\delta^{13}C$ with time. In the present case study the commonly applied approach underestimated total SOC loss by 6 to 32%, overestimated decomposition by 13 to 40%, and overestimated SOC input by 14 to 41% compared to the CIDE derived values (calculated for 15 years after land use change).

Key message 2: Soil texture had a high impact on soil erosion and SOC dynamics

High clay content favored humification (R^2=0.37), decomposition (R^2=0.56), the formation of stable aggregates (R^2=0.68) and resistance against soil erosion (R^2=0.82). The increase in decomposition with increasing clay content was attributed to the decomposition of labile SOC which was attached to clay particles in the sand sized stable aggregate fraction. The stable aggregate fraction was largely responsible for the variation in bulk SOC decomposition between the sites.

Key message 3: Tillage Increased erosion and decomposition

Comparison of decomposition in the depth layers revealed that tillage accelerated decomposition, accounting for 3 to 35% of total decomposition. Tillage-induced soil flux accounted for 38 ± 3 kg m^{-1} per tillage pass. Soil erosion by water was higher than tillage-induced erosion in middle and foot slope positions, accounting for 86 to 89% of total soil erosion.

Key message 4: Land use change from forest to malze led to net SOC decline and net bulk soll erosion

SOC stocks declined exponentially after land use change from forest to maize. Along the three chronosequences net SOC loss accounted for 47.1 to 63.5% (4.3 to 4.8 kg m^{-2}) of initial SOC stocks at 0-30 cm depth 15 years after land use change. The sum of SOC loss by decomposition and erosion accounted for 4.6 to 5.3 kg m^{-2} 15 years after land use change, of which 18.1 to 54.9% were attributed to eroded SOC. Maize derived SOC input rates were similar on all soil types, accounting for 0.02 to 0.03 kg m^{-2} a^{-1} which is more than one order of magnitude smaller than SOC loss during the observation period.

Soil erosion was determined by a ^{137}Cs based method. Net soil erosion rates of the investigated sites ranged from 12 to 89 t $ha^{-1}a^{-1}$. A large part of the variation in bulk soil erosion (R^2=0.79) and SOC erosion (R^2=0.67) between the sites was simply but effectively explained by the ratio of site specific cumulative RUSLE LS factors (function of time since land use change and relief position) to clay content.

How to reduce SOC loss and lncrease SOC input?

Current land management is far from being sustainable. To reduce net SOC loss and increase SOC input it is suggested that minimum tillage techniques and erosion protection measures be implemented, soil cover at the beginning of the rainy season be Increased, harvest residues be used as mulch, residue burning be abandoned, and that instead residues be chaffed and fruit trees be planted on steep slopes. It was calculated for a 10 year old site that, if all practices would be applied, a maximum net SOC loss reduction of 70% could be achieved within one year on Alisol, 95% on Vertisol, and on Luvisol even a SOC sequestration of 30% could take place.

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