Distribution and stabilization of organic carbon in Danubian floodplain soils

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Abstract
Floodplain soils are assumed to act as sinks for organic carbon (OC). To date, our knowledge on OC distribution and stabilization in these soils is only weak. We investigated OC stocks at 76 sampling sites in the Danubian floodplains and conducted density fractionation of selected soil samples. The soils were found to contain huge stocks of OC. The distribution (horizontal and vertical) of OC stocks and other soil properties is highly heterogeneous and determined by sedimentation dynamics. First results of density fractionation of organic matter (OM) and aggregate stability tests indicate that soils developed under different sedimentation conditions differ in the relevance of the different OM stabilizing mechanisms. Occlusion of OM within aggregates is more important in soils developed under dynamic sedimentation conditions, whereas formation of organo-mineral complexes is determining OM stabilization in soils developed under static sedimentation conditions. Testing aggregate stability is crucial to assess OM stabilization.

Key Words
Riverine floodplains, carbon sequestration, density fractionation, aggregate stability, ultrasound.

Introduction
Mineral soils of riverine floodplains often hold high stocks of organic carbon (OC) in both topsoil and subsoil horizons and are assumed to act as sink for OC (Batjes 1996). Two different mechanisms of OC enrichment are important in these soils: the sedimentation of allochthonous OC rich material during flood events (Pinay *et al.* 1992) and the above-average production of biomass within the floodplains (Giese *et al.* 2003, Naiman and Décamps 1997). To date, little data on the spatial distribution (horizontal and vertical) of OC and the mechanisms of organic matter (OM) stabilization in these soils is published. Aims of the study presented are to determine the distribution of OC stocks in the floodplains of the Danube river and to identify the influence of sedimentation dynamics on OM stabilization. In this context, we focus on the stabilization of OM within aggregates.

Methods
Investigation area and soils
Our study site is located in the "Donau-Auen National Park" near Vienna (Austria), one of the few remaining near-natural floodplain landscapes in Europe. Soils and vegetation were surveyed at 76 sites within an area of roughly 1.300 ha representing the typical riparian forest ecosystem of the national park (Figure 1). Vegetation structure and sedimentation dynamics were found to be closely related to each other. Using vegetational and geomorphological variables we identified a gradient in sedimentation dynamics (Cierjacks *et al.* in press). In addition, the horizons of seven soil profiles along this gradient were sampled.

OC stocks
Soil carbon content was determined in milled soil samples using a catalytic dry combustion CN-Analyser (Elementar®). Organic carbon content was calculated as the difference of total carbon content and carbon content of combusted (550°C) soil samples following Bisutti *et al.* (2006). OC stocks were calculated for each soil horizon based on OC concentration and bulk density.

Determination of OM stabilizing mechanisms
We run a density fractionation basically described by Golchin *et al.* (1994) and Grünwald *et al.* (2006) with the soil samples to fractionate organic matter (OM) based on its binding mechanism to soil components. Hereby, we are able to identify the amount of free, particulate organic matter (fPOM), intra-aggregate particulate organic matter (iPOM) and organic matter associated to mineral surfaces (MOM). These

operationally defined fractions differ in their grade of stability against mineralization and OM turnover times, consequently (von Lützow *et al.* 2006). The air-dried and sieved (< 2mm) bulk soil was put into sodium polytungstate (SPT) solution with a density (ρ) of 1.6 g/cm^3. The fPOM fraction was separated in the first step (ρ <1.6 g/cm^3), afterwards soil aggregates were destroyed by applying an adjusted amount of ultrasonic induced energy. The released iPOM fraction (ρ <1.6 g/cm^3) was removed and MOM (ρ >1.6 g/cm^3) remains within the SPT solution.

Determination of aggregate stability
In a further experiment we will determine soil aggregate stability. We will use a standard ultrasonic device (Branson W-250®) and a high-precision ultrasonic device described by Mayer *et al.* (2002) which allows to determine the emitted energy by measuring the vibration amplitude. We will analyze dispersed particles after exposure to different amounts of energy. This will help to identify and to classify different energies of aggregate bonding. The data will be linked to the investigation on OM stabilization mechanisms.

Results
OC stocks in Danubian floodplains
Organic carbon stocks in the investigation area ranged between 42 and 354 t/ha (1 m in depth) with an average of 177 t/ha (distribution is shown in Figure 1). Large OC stocks are mainly found at sites with static sedimentation conditions. These stocks are huge compared to other terrestrial ecosystems (tropical rain forest 122-123 t/ha, temperate deciduous forest 96-147 t/ha, data taken from Prentice *et al.* 2001) and reveal that the area acts as a sink for OC. The large amount of OC sequestrated in the investigated floodplains is in line with findings of other studies on the OC sequestration potential of riverine floodplain soils (e.g. Giese *et al.* 2003).

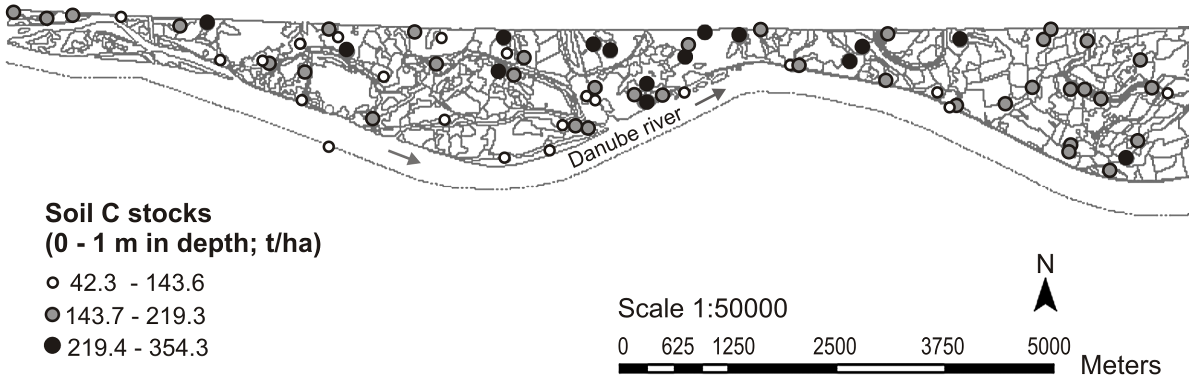

Figure 1. Distribution of OC stocks in the study area at the Danubian floodplains.

Aggregate stability in floodplain soils
First results show that aggregate stability varies among the investigated soils (Figures 2 and 3). Soil 1 contains the most stable aggregates: An application of 400 J/mL still causes disruption of aggregates (OM mass yield, see Figure 3) without releasing OM from mineral surfaces (OC content 30 to 37 %, Figure 2). Soil 2 contains aggregates of lower stability. After applying energy of 100 J/mL iPOM is released (OM mass yield found, OC content 35%), whereas higher energies obviously lead to a dispersion of soil minerals and lower OC contents and no significant mass yields, consequently. Soil 3 reveals the least stable aggregates. The application of 50 J/mL releases POM occluded within aggregates (OM mass yield found, OC content 41%), higher energy levels cause the release of OM from mineral surfaces as indicated by decreasing OC contents and the absence of additionally extracted material.

OM stabilizing mechanism in floodplain soils
Results of density fractionation carried out with samples of topsoil and subsoil horizons developed under static and dynamic sedimentation conditions are shown in Figure 4. In all soils the distribution of recovered OC decreased in the following order: MOM >> iPOM > fPOM. All subsoil samples contain a lower relative amount of POM (fPOM and iPOM) than found in topsoil samples. Soils developed under dynamic sedimentation conditions are characterised by higher portions of recovered OC found occluded in aggregates compared to soil deriving from more static sedimentation conditions. Higher portions of occluded OC suggest a higher importance of aggregate formation for OM stabilization under dynamic than under static sedimentation conditions. As opposed to that association of OM to mineral surfaces is more dominant in soils developed under static sedimentation conditions.

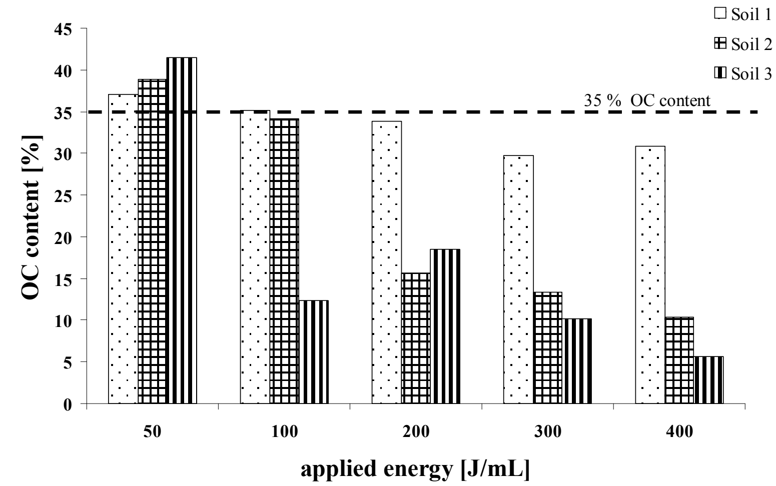

Figure 2. OC content [%] of material gained after application of different amounts of ultrasonic energies. Soils representing different aggregate stability are shown.

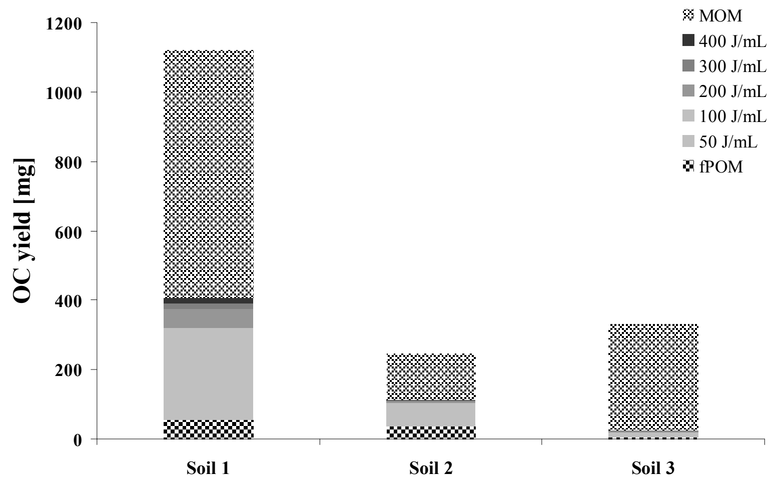

Figure 3. OC mass yield after density fraction and different energy levels to obtain aggregate occluded POM. Soils representing different aggregate stability are shown.

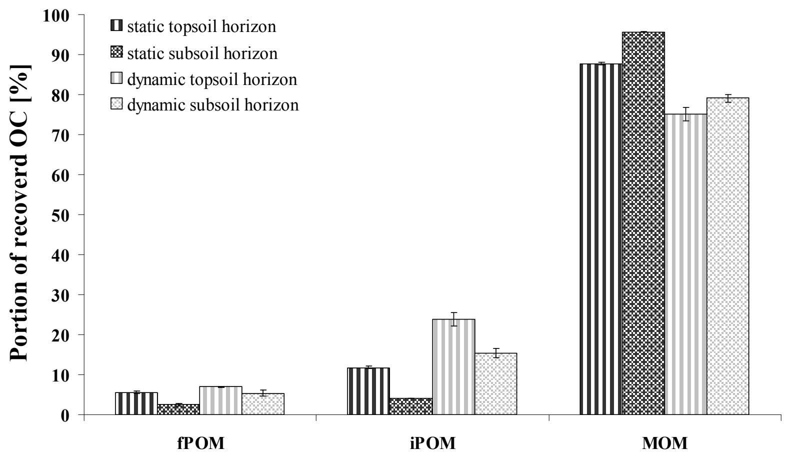

Figure 4. Distribution of recovered OC between fPOM, iPOM and MOM of topsoil and subsoil horizons developed under static and dynamic sedimentation conditions, respectively.

Conclusion

Sedimentation conditions control OM distribution (horizontal and vertical) and stabilization, as well as aggregate stability. For the assessment of the OC sequestration potential sedimentation conditions have to be considered. With focus on the importance of aggregates for overall OM stabilization ultrasonic experiments will help to understand the differences between 'static' and 'dynamic' sites.

References

Batjes NH (1996) Total carbon and nitrogen in the soils of the world. *European Journal of Soil Science* **47,** 153-163.

Bisutti I, Hike I, Lober K (2006) Duale Temperatur-Verbrennung (DTV) im Einsatz: Analytische Bestimmung des organischen Kohlenstoffs (OC) in Bodenproben. *GIT* **50,** 1111-1113.

Cierjacks A, Kleinschmit B, Babinski M, Kleinschroth F, Markert A, Menzel M, Ziechmann U, Schiller T, Graf M, Lang F (2010) Carbon sequestration by soil and vegetation on Danubian floodplains. *Journal of Plant Nutrition and Soil Science* (in press).

Giese LA, Aust WM, Kolka RK, Trettin CC (2003) Biomass and carbon pools of disturbed riparian forests. *Forest Ecology and Management* **180,** 493-508.

Golchin A, Oades JM, Skjemstad JO, Clarke P (1994) Study of Free and Occluded Particulate Organic matter in Soil by Solid state ^{13}C CP/MAS NMR Spectroscopy and Scanning Electron Microscopy. *Australian Journal of Soil Research* **32,** 285-309.

Grünewald G, Kaiser K, Jahn R, Guggenberger G (2006) Organic matter stabilization in young calcareous soils as revealed by density fractionation and analysis of lignin-derived constituents. *Organic Geochemistry* **37,** 1573-1589.

von Luetzow M, Kögel-Knabner I, Ekschmitt K, Matzner E, Guggenberger G, Marschner B, Flessa H (2006) Stabilization of organic matter in temperate soils: mechanisms and their relevance under different soil conditions – a review. *European Journal of Soil Science* **57,** 426-445.

Mayer H, Mentler A, Papakyriacou M, Rampazzo N, Marxer Y, Blum WEH (2002) Influence of vibration amplitude on the ultrasonic dispersion of soils. *International Agrophysics* **16,** 53-60.

Naiman RJ, Décamps H (1997) The ecology of interfaces. Riperian Zones. *Annual Review of Ecological Systems* **28,** 621-658.

Pinay G, Fabre A, Vervier P, Gazelle F (1992) Control of C, N, P distribution of riparian forests. *Landscape Ecology* **6,** 121-132.

Prentice IC, Farquhar GD, Fasham MJR, Goulden ML, Heimann M, Jaramillo VJ, Kheshgi HS, Le Quéré C, Scholes RJ (2001) The carbon cycle and atmospheric carbon dioxide. In ‘Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change (Eds JD Houghton, Y Ding, DJ Griggs, M Noguer, PJ van der Linden, X Dai, K Maskell) pp 183-237. (Cambridge University Press: Cambridge UK and New York).