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Changes in SOM under short-rotation forestry with fast growing tree species

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1 Introduction

The potential of soils to store carbon is strongly affected by land use and land use changes. In order to preserve natural landscape and reduce greenhouse gas emission at the same time, any essential increase in agricultural output must be made in a sustainable fashion. One approach is a “multifunctional agriculture”. Apart from primary food production, this includes the cultivation of renewable resources as a primary objective. For example, with the production of energy crops, short-rotation forestry (SRF) can contribute to climate protection. Moreover, afforestation with fast growing tree species on former arable soils may increase soil organic carbon (SOC) contents due to the reduction in soil cultivation frequency.

These considerations lead to the following questions:

i) Is there a long-term increase in carbon storage under current SRF schemes; and
ii) Is this carbon storage under SRF sustainable; what are the consequences of transforming forest soils back into arable land?

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2 Materials and Methods

The investigations were carried out within the DFG-funded project „The mycorrhiza-mediated pathway for soil organic matter (SOM) formation and consequences for the SOM turnover under short rotation forestry“. In our subproject we compared soil carbon stocks of ongoing short rotation forestry (SRF) and former forestry fields (f-SRF). Two current (SRF) and two former (f-SRF) (*Populus nigra x P. maximowiczii*) test sites in different temporal stages of change were selected, with corresponding reference sites (REF) in each case (Tab. 1).

Table 1: sites and location

site	location	forestry	actual use
Gülzow (GUL) **SRF**	Mecklenburg-Pommerania	since 1993	short rotation forestry
Cahnsdorf (CAH) **SRF**	Mecklenburg-Pommerania	since 2006	short rotation forestry
Vipperow (VIP) **f-SRF**	Brandenburg	1993-2007	annual crop
Methau (MET) **f-SRF**	Saxonia	1997-2007	annual crop

We took five independent cores of 8 cm diameter per replicate in the topsoil, yielding 15 cores per treatment. Our cores were divided into 5 depth increments: 0-5, 10-15, 15-20 and 20-30 cm.

Samples were dried, screened for fine roots and stones, sieved at 2 mm, homogenized by grinding, and weighted prior to quantifying the total carbon (C_t) and total nitrogen (N_t) content by elementar analysis. Organic carbon (C_{org}) was determined indirectly by $C_{org} = C_t - C_{inorg}$. Inorganic carbon ($C_{inorg}$) was measured after thermal pre-treatment of a subsample (muffle furnace, Hereaus, 450°C, 16h) by elemental analysis as well (vario Max, Elementar Analysensysteme GmbH Hanau).

The determination of SOC-stocks for fixed volumes follows equation 1. The content of organic carbon (C_{org}) was then related to layer thickness (~), content of stones (ST) and bulk density (BD) (Eq. 2), which was corrected by dry mass (TS). Each sample i was calculated according to:

$$(1) \qquad OC - stock_i\,[kg\ m^{-2}] =$$

$$Corg_i\,[g\ kg^{-1}] * \frac{Corg_i\,[g\ kg^{-1}] * BD_i\,[g\ cm^{-3}]}{ST_i\,[g\ kg^{-1}]} * \sim [cm]$$

$$(2) \qquad BD_i\,[g\ cm^{-3}] = {m_i[g]}/{V_i[cm^{-3}]}$$

3 Results

The analysis of SOC-stocks (Fig. 1) showed an accumulation up to 0.2 kg m^{-2}

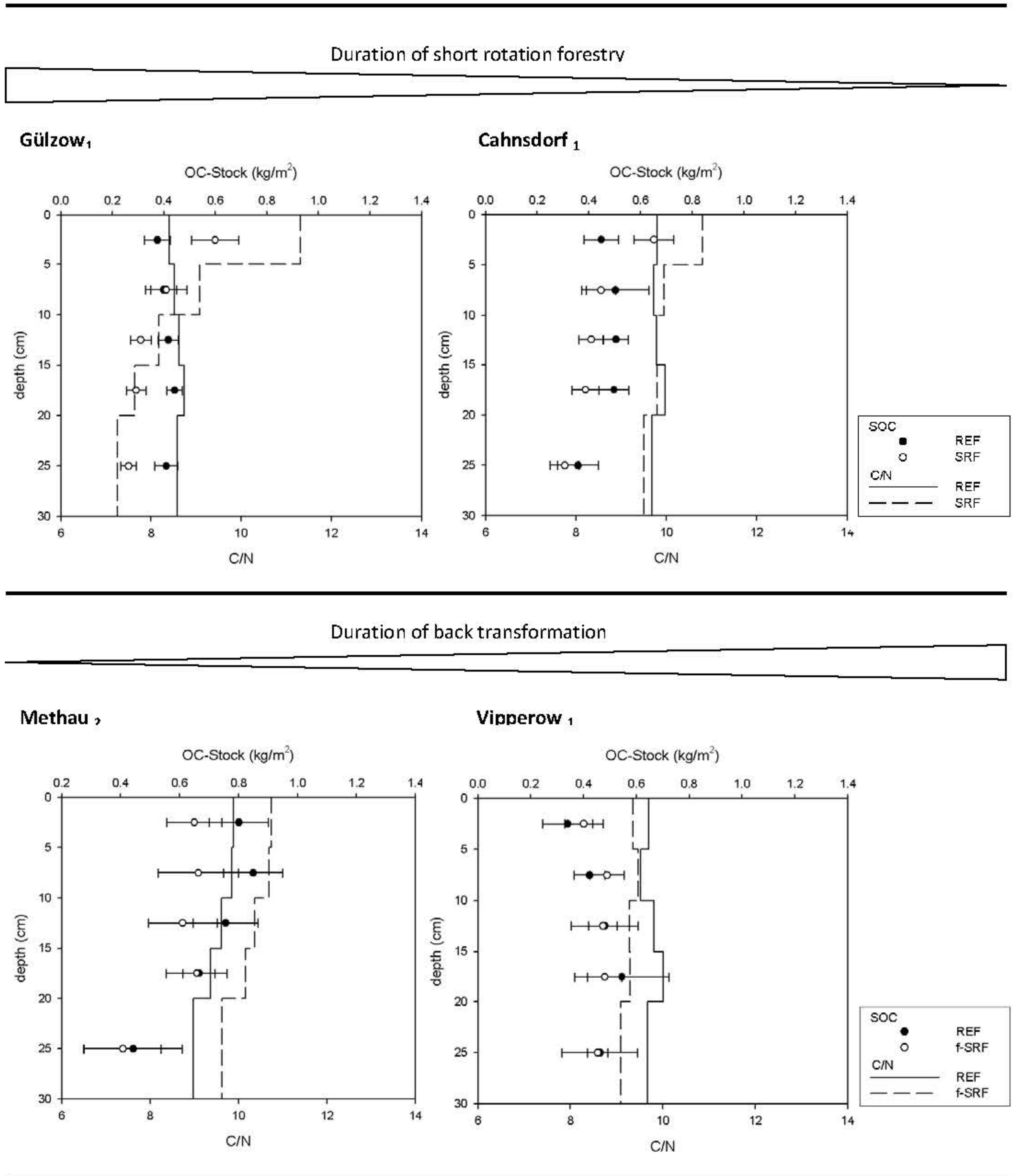

Figure 1: Mean and standard deviation of OC-stock (kg m^{-2}) and bulk density (g cm^{-3}) and mean of C/N ratio of investigated short rotation (SRF, f-SRF) and reference sites (REF). $_1$ data from 2012, $_2$ data from 2013

in top layer (first 5 cm) for current SRF (GUL, CAH) in comparison to the REF plots. In contrast, an increase in SOC at lower horizons was found for the REF plots, with a mean of 0.1 kg m^{-2}. However, the vertical differences in soil of former SRF (VIP) were lower than 0.09 kg m^{-2}. In comparison to REF plots the detectable differences in SOC-stock were lower than 0.06 kg m^{-2}. The C/N ratio was higher in top layers of current SRF in contrast to REF (Fig. 1). In older plantation (GUL), the differences from top layer to 30 cm were clearly higher with 4.0 kg m^{-2} compared to younger SRF (CAH) with 1.2 kg m^{-2}. Related REF plots displayed constant ratios over all soil horizons. Former plantation (VIP) showed neither a vertical stratification nor differences in contrast to REF. The C/N ratio of site MET slightly decreased with depth at the same degree for both plots.

Table 2: Total SOC-stock (kg m^{-2}) for all sampled sites. * data from 2013

∑SOC-stock (kg m^{-2})	2011 (f-)SRF	2011 REF	2012 (f-)SRF	2012 REF
GUL	2.146	1.906	1.877	2.043
CAH	2.211	2.132	2.201	2.312
VIP	2.122	2.326	2.299	2.252
MET	2.595	-	2.991*	3.516*

To assess the total carbon storage for (f-)SRF and their related REF sites, we added the SOC-stocks per layer for each soil core. The total stock per site results from the mean of these summarized values. Referring to total SOC-stocks, there are differences between (f-)SRF and their related REF sites (Tab. 2). With the exception of VIP, the SRF sites which were sampled during 2012 and 2013, respectively, displayed lower values than the related REF sites. In contrast, the results of the 2011 sampling campaign showed higher stocks under (f-)SRF than under agricultural land use (REF). The back-transformed f-SRF site VIP is an exception again. Conversely to 2012, we found a lower total SOC-stock compared to the REF site in 2011. Altogether, no sustainable carbon storage under f-SRF sites could be detected. Measured differences in total SOC could not be attributed to the effect of plantation, but have to be ascribed to annual variability of each site.

4 Conclusions

We found an accumulation of SOC in topsoil of current long-term SRF in comparison to REF, but lower C content in the subsoil (Fig. 1). The CN ratio increased through higher C_{org} and total N accumulation under SRF. In former SRF sites accumulation of C_{org} was not detectable and we found no increase in the total SOC-stocks per site. Effects are marked by soil treatment. Variance in total accumulation of C_{org} (Tab. 2) occurs in spatial distribution of investigated areas (e.g. different soil type, local climate, land use) and was effected by its annual variabilities. Combined, the investigations results in following:

i) SRF changes the carbon distribution in the anthric horizon. However, a total carbon storage change could not be detected.
ii) The differences in carbon distribution were quickly removed by planting.