The CarboZALF-D manipulation experiment – experimental design and SOC patterns

Detlef Deumlich[1], Helmut Rogasik[2], Wilfried Hierold[3], Ingrid Onasch[4], Lidia Völker[5], Michael Sommer[6]

[1-6]Leibniz Centre for Agricultural Landscape Research Müncheberg (ZALF) , Institute of Soil Landscape Research, Eberswalder Straße 84, 15374 Müncheberg, Germany

[6]University of Potsdam, Institute of Earth and Environmental Sciences, 14476 Potsdam, Germany

***Abstract*— The CarboZALF-D manipulation experiment – experimental design and SOC patterns**

Soil erosion by water or tillage is an essential landscape-shaping factor with feedbacks to the carbon cycle. To study C dynamics and C balances as a function of soil erosion we set up a manipulation experiment at field scale, called "CarboZALF-D". A defined amount of topsoil material was removed from an eroded Luvisol towards a Colluvic Regosol and reactive, clay-enriched subsoil material was blended into the topsoil of the eroded Luvisol. By doing so we induced transient states for C cycling, net fluxes of CO_2 and the C balance. The overall aim of our experiment is to get reliable findings to answer the question: Does soil erosion causes a CO_2 source or sink in arable landscapes? In this paper the concept, implementation, and preliminary results of the manipulation experiment are described.

***Keywords*— bulk density, carbon stock, manipulation experiment, simulated erosion, SOC pattern.**

I. INTRODUCTION

Soil erosion is an essential factor for shaping landscapes [1], [2], e.g., for the Uckermark region in the Northern German lowland [3]. Until now, its influence has primarily been examined for differing slope positions or the soil's function [4], [5]. An erosion-attributed decrease in topsoil depth and nutrient content leads to yield reduction in erosion positions, whereas the aggradation area shows partly positive effects. Erosion is a process with complex factors and can be difficult to predict. It occurs at all scales of the landscape, from the soil aggregate to the landscape scale [6], [7], [8]. In order to examine its influence on the C budget, defined conditions are necessary. One way to achieve those are controlled manipulation experiments at plot or field scale. A number of manipulation experiments had been set up at plot scale in the past. Defined alteration or adjustment of soil properties are a profound tool for experiments [9], [10], [11]. Practical applications in agricultural sciences, in addition to laboratory experiments, demonstrate impact in the field, e.g. fertilization levels for organic mineral fertilizers and their effect on yield and soil functions, initiation of soil compaction for a clarification of soil reloosening processes [12], influence of CO_2 management on yield [13], influence of soil cover on soil loss and runoff [5], and influence of different erosion rates on yield [14], [15]. Field scale manipulation experiments, like relief [16] and summit amelioration [17], aimed to improve site conditions and plant production. Generally, changes in soil properties by soil erosion were examined by means of a comparison before and after a soil erosion event, e.g., using rainfall simulators or laboratory experiments. However, these studies have not been directly related to CO_2 emissions. Körschens et al. [18] pointed out that changes in soil organic matter (SOM) are very slowly and can only be detected and verified after decades by using a mass balance approach.

In non-redoximorphic soils SOM is related to textural parameters, like clay and fine silt under steady state conditions [19], [20], [21], [22], [23]. However, if textural properties in topsoils are changed by erosion feedbacks to the C cycling, hence SOM, will occur as texture also affects related chemical, physical and biological properties. This has been tested in long-term studies [24], experiments on the influence of topsoil reduction [25], [26], bentonite fertilization [21] and deep ploughing of soils (30 to 60 cm) bringing subsoil material into the Ap horizon [9].

However, there is no manipulation experiment at field scale, which includes both, erosional and depositional soils representing different landscape scale process domains in terms of C dynamics and C balances. Therefore we established the CarboZALF-D manipulation experiment. The concept, implementation, and preliminary results of which are described below.

II. MATERIAL AND METHOD

2.1 Environmental setting and experimental design

The CarboZALF-D site (53°22’47” N, 13°47’06” E) is located in the Uckermark region of NE Germany (Fig. 1). The subcontinental climate is characterized by a mean annual rainfall of 483 mm and an average air temperature of 8.7°C (1992–2011, ZALF research station Dedelow). The experimental site ranges from 50m to 60 m a.s.l. The site represents a typical soil landscape of hummocky ground moraines in NE Germany with Albic Cutanic Luvisols at non-eroded sites, Calcic Cutanic Luvisols at moderate slopes, Calcaric Regosols at steep slopes and convex knolls, and Endogleyic Colluvic Regosols (Eutric) over peat in the hollow [27].

FIGURE 1. EXPERIMENTAL SITE CARBOZALF-D IN THE UCKERMARK, NE GERMANY, WITH MANIPULATION PLOTS.

Digital soil maps at a scale of 1:5,000 to 1:25,000, terrain analysis on basis of digital elevation models (DEM 1 to DEM25) as well as geophysics were used as input data for a GIS analysis to delineate experimental plots of minimized soil and terrain heterogeneity. Intensive soil sampling (approx. 200 cores and 14 soil pits) and subsequent lab analysis constitutes the basis for a spatial modelling of Soil organic carbon (SOC = SOM/1.724)) and erosion patterns [28], [29].

Two plots of the experimental area were chosen for the manipulation experiment according to relief and soils: plot 11 (slope of 5 – 7 %) and plot 10 (slope of 2 – 5 %). Plot 11was chosen as representative for moderately eroded areas with Calcic Luvisols (Cutanic) (LV-cc-ct, [27]; in German: and “erodierte, pseudovergleyte (Acker)Parabraunerde” (e.s.vLL, [30]), respectively. Plot 10 represents depositional areas with Endogleyic Colluvic Regosols (RG-gln.co, [26]); in German: and “Gley-Kolluvisol” (vGG-YK, [29]), respectively. Selected soil parameters of the described soil profiles of both plots are shown in Table 1. They were used to calculate the targeted soil conditions after manipulation. Bulk density (BD) and SOC contents were determined after the manipulation in 5m x 5 m grids to estimate the quality of the manipulation (April to May 2011). At each point the upper and lower Ap-horizon was sampled separately by 100 cm^3 cores (7-12 cm and 17-22 cm depth) as well as composite samples from 0-15 cm and 15-30 cm depth.

For geostatistical investigations isotropic semivariograms were created for bulk density, SOC and SOC stock distribution, by means of GS+ Gamma Design software, Plainwell, MI, Version 10

TABLE 1
SOIL PROPERTIES FOR THE AP-HORIZON OF REFERENCE PROFILES (MANIPULATED AND NEIGHBOURING NON-MANIPULATED PLOTS, SEE FIG. 1 FOR LOCATIONS)

Profile (plot)	12n	12s	11n	11s	10n	10s	9n	9s
	non manipulated		manipulated				non manipulated	
Soil-Subtype(KA5)[1]	e.s.vLL				vGG-YK			
WRB (2014)	Calcic Luvisols (Cutanic) (LV-cc-ct)				Endogleyic Colluvic Regosols (RG-gln.co)			
Ap-horizon								
Depth [cm]	0-30	0-25	0-30	0-30	0-30	0-30	0-30	0-30
Skeleton [%]	3.2	2.6	2.9	2.7	2.4	2.7		
Bulk density [Mg m^{-3}]	1.48	1.43	1.66	1.43	1.59	1.44	1.74	1.58
Sand (%; 2-0.063 mm, KA5)	61	61	59	60	60	60	59	59
Silt (%; 0.063- 0.002 mm, KA5)	27	29	28	27	28	30	31	31
Clay (%; <0.002 mm, KA5)	12	10	13	13	13	13	10	10
Clay (cl)+fine silt (fsi) [%] KA5	**14.8**	**13.5**	**16.3**	**17.8**	**16.2**	**17.7**	**14.9**	**14.4**
Soil textural class (KA5)[2]	Sl3	Sl3	Sl4	Sl4	Sl4	Sl4	Sl3	Sl3
Nitrogen total [g kg^{-1}]	0.99	0.85	0.84	0.81	1.07	0.94	1.05	0.88
SOC initial [g kg^{-1}]	8.3	8.8	8.2	8.5	10.8	10.1	9.6	8.5
SOC-target [g kg^{-1}][3]	8.9	8.4	9.5	10.1	8.7	8.5	8.9	8.8
Solum-depth [cm]	60	58	70	40	>200	>200	>200	>200
SK-category (Table 3)	1	0	1	1	0	0	0	1

[1]***erodierte, pseudovergleyte (Acker-)Parabraunerde (e.s.vLL), vGG-YK – Gley-Kolluvisol;***
[2] ***Sl3 – medium loamy sand, Sl4 heavy loamy sand (acc. KA5, [30]);***
[3] ***SOC-target [%] = (cl+fsi)*0.04 + 0.3 (acc. Eq. 5)***

Additionally large soil cores (height = 250 mm; diameter = 200 mm) were taken and scanned by X-ray computed tomography at the Leibniz-Institute for Zoo and Wildlife Research (Toshiba Aquilion Scanner with scanning energy level of 135 kV and 300 mAs). Slice thickness was 0.5 mm and pixel size 0.5 * 0.5 mm².

2.2 Pre-calculations for the manipulation experiment

Based on the literature (see introduction) the following soil properties were used for an a-priori calculation of the intended manipulation effect: texture, SOC, bulk density (BD) and soil skeleton content (> 2mm). We aimed to substitute 25% of the respective Ap horizon in plots 10 and 11. By doing so we simulate a severe erosion event and clearly induced new system state of transient character. The calculation of the transported soil volume was performed using data from Table 2.

TABLE 2
CALCULATION OF BT SOIL MASS FOR MANIPULATION

Reference Profile	Horizon	Depth	Skeleton	BD avg.	Fine soil (Solum)	Ap-mass (0.25 m tillage depth)	Ap- Bt-share	new mass
		cm	Weight %	Mg m^{-3}	kg m^{-2}	kg m^{-2}	%	kg m^{-2}
11 n	Ap	0-30	3	1.66	484	390	0.8	312
	(Bt)						0.2	78
11 s	Ap	0-30	3	1.4	433	338	0.8	270
	(Bt)						0.2	67
Average of manipulated mass								73

$$\text{Mass fine soil [kg m}^{-2}\text{]} = \text{thickness} * 100 * ((100 - \%\ \text{skeleton})/100) * \text{BD} \quad (1)$$

$$\text{Ap-mass with 25 cm tillage depth} = \text{fine soil [kg m}^{-2}\text{]} * \text{25cm depth of Ap} \quad (2)$$

New soil mass = Ap-mass with 25 cm tillage depth * 0.2 (planned share of 20%) (3)

The average Ap soil mass, which was replaced by soil material from a Bt, was 73 kg m^{-2}. The area of plot 11 with 1,200 m^2 required removal of 90 Mg Ap soil material.

The soil depth (man_Ap) to be removed was calculated:

man_Ap = new soil mass/(BD * ((100- % skeleton)/100)) (4)

As a result five to six cm of topsoil were removed from the erosion site (plot 11), transported to the hollow and admixed into the Ap of plot 10. The soil mass removed from plot 11 was replaced 1:1 with clay-enriched subsoil material (Bt). In consequence, Ap properties were altered extensively.

2.3 Manipulation procedure

The manipulation took place on October 6, 2010 under optimal weather and soil conditions (Fig. 2). Driving on the field with machinery was done similar to on-land ploughing pulled by a tractor. Thus, during the lifting of the soil, additional compaction of the soil was minimized. For the application of the manipulation, a digger "CAT M316 C" with dozer blade rented from a local business was used and operated by an experienced machine operator. The truck for soil transport (3-axis-dumper MAN 27372) was weighed for every load, after capturing the tare weight. The dump truck had an estimated volume of ca. 8.5 m^3 (Width = 2.1 m, Height = 0.9 m, Length = 4.5 m). Plot 11 of 1,200 m^2 in size was manipulated first. The topsoil of this area was moved to the plot 10.

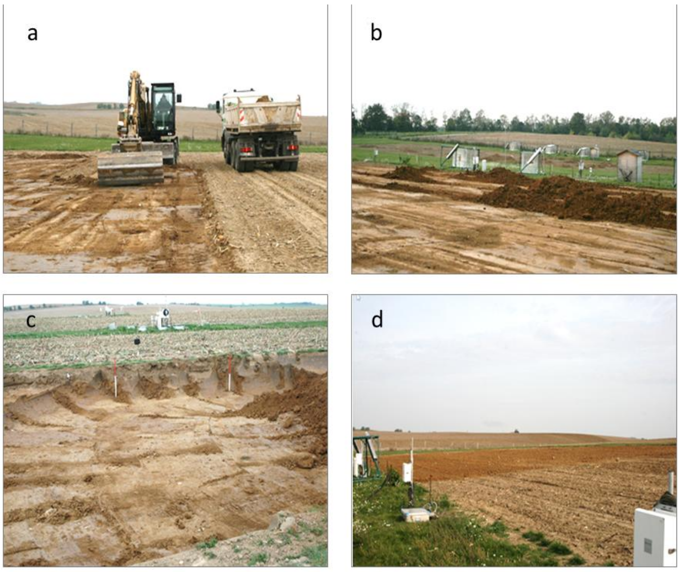

FIGURE 2. MANIPULATION PROCEDURE (OCTOBER 2010): (A) REMOVAL OF 6 CM AP AT PLOT 11, (B) ADDITION OF THE AP MATERIAL FROM PLOT 11 TO PLOT 10, (C) EXCAVATION OF BT (NEARBY PLOT 1), (D) SOIL SURFACE OF PLOT 11 AFTER HOMOGENIZATION.

2.4 Pedotransfer functions for SOC target

Körschens [19] developed a soil fertility indicator for soil organic matter. First he derived an achievable SOC content from long-term field experiments, further on referred to as the "SOC target", which is equivalent to the concept of "carbon saturation potential" [22], [31]. This SOC content reflects steady state conditions for Ap horizons of diluvium sites within the Northeastern German lowland and depends on the clay (cl) and fine silt (fsi) content (< 0.0063 mm, German Soil Classification System, [29]) (Eq. 5):

SOC-target [%] = (cl+fsi)*0.04 + 0.3 (5)

If the actual SOC is below that value, amelioration through organic fertilization was claimed. If actual SOC contents are below calculated value according to Eq. 6 a very low soil fertility has to be stated.

C-„inert"[%] = (cl+fsi)*0.04 (6)

Both regression equations (Eq. 5 and Eq. 6) were the basis for defining three soil fertility categories (SK0, SK1, SK2; Table 3). This led to recommendations for ameliorations with organic fertilization (large quantities of manure) or changes in land use [32]. SK0 is equivalent the carbon saturation potential, soils belonging in classes SK1 or SK2 have a potential to sequester C, which can be quantified as the difference between SOC at SK0 and the actual SOC content.

TABLE 3
CATEGORIES OF SOIL FERTILITY REDUCTION (SK).

SOC-ini* ≥ [cl+fsi] * 0.04 + 0.3	SOC-ini > [cl+fsi] * 0.04	SOC-ini ≤ [cl+fsi]*0.04
SK0	SK1	SK2
optimal SOC-content	suboptimal SOC-content	insufficient SOC-content

III. RESULTS

The bulk density of the upper 5 cm of plot 11 before the onset of the manipulation slightly deviated from this measured the year preceding the manipulation. The measured density 1.57 Mg m^{-3} was typical of the post-harvest period. Under this assumption a theoretical volume of 60 m^3 (1,200 m^2 * 0.05 m layer thickness) or 90 Mg of Ap had to be moved, respectively. However, weighing of the transported material yielded only ca. 79 Mg (six truck loads). This soil mass was replaced by clay-enriched subsoil material (Bt) from the plateau area.

The intended change of soil properties was achieved as can be seen by calculated texture, SOC content, the changes in SOC from the grid sampling as well as other properties of the Ap horizon. (Fig. 3, Table 4).

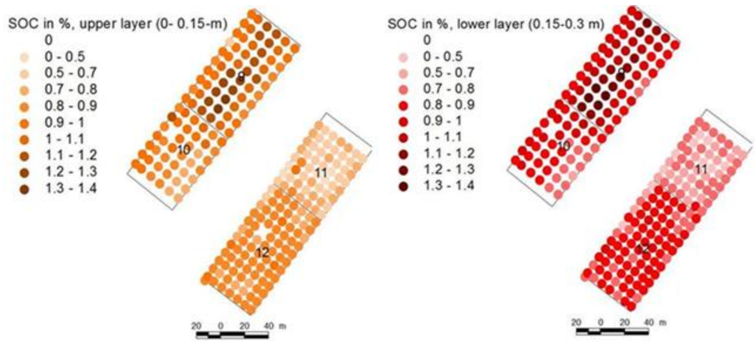

FIGURE 3. SOC CONTENT OF UPPER (0-0.15 M) AND LOWER AP-LAYER (0.15-0.30 M) IN THE 5M GRID.

TABLE 4
TEXTURE CLASS AND SOIL ORGANIC MATTER (INITIAL/QUOTA) CALCULATED FOR MANIPULATED PLOTS.

Property / Plot/horizon	s	fsi	si	cl	Textural class	SOC initial	SOC target	C-inert	SK
	%	%	%	%		%	%	%	
Ap from P11	60	5	27	13	Sl4	0.76	0.99	0.69	1
Bt from Top	54	4	27	19	Ls4	0.21	1.22	0.92	-
Ap10n	61	4	28	11	Sl3	1.08	0.90	0.60	0
Ap10s	60	4	30	10	Sl3	1.01	0.86	0.56	0
avg. Plot10	**61**	**4**	**29**	**10**	**Sl3**	**1.04**	**0.87**	**0.57**	**0**
Ap11n	59	4	28	13	Sl4	0.82	0.96	0.66	1
Ap11s	60	5	27	13	Sl4	0.85	1.02	0.72	1
avg. Plot11	**60**	**4**	**27**	**13**	**Sl4**	**0.84**	**0.99**	**0.69**	**1**
Plot after manipulation									
Ap10_new-calculated	**61**	**4**	**28**	**11**	**Sl3**	**0.98** **-5%** [1]	**0.90**	**0.60**	**0**
Ap10_new-measured						**0.87** **-15%** [2]			**1**
Ap11_new-calculated	**58**	**4**	**28**	**14**	**Sl4**	**0.71** **-15%** [1]	**1.02**	**0.72**	**2**
Ap11_new measured						**0.67** **-20%** [2]			**2**

[1] calculate using two reference profiles
[2] average of raster based measurements

Abbreviations: S-sand, fsi-fine silt, si-silt, cl-clay, C-carbon, SK- Categories of soil fertility cf. Table 3; Ap-arable horizon, Bt-clayey subsoil

Comparing initial conditions and the new status after manipulation a SOC decrease of 15% in plot 10 and 20% in plot 11 was achieved. The SOC change at plot 10 led to a switch from categories SK0 to SK1 (degradation) and at plot 11 from SK1 to SK2 (insufficient) (SK in Table 4). The manipulation barely changed the texture of either plots, whereas the SOC decreased considerably (Table 4). Due to the manipulation plot 11 shows a theoretical C sequestration potential of 1,400 g C m^{-2} (CO_2-C sink of 14 Mg C ha^{-1}), which should lead to CO_2 net influxes into the soil-plant system. At plot 10 a C sequestration potential of 670 g C m^{-2} (CO_2-C sink of 6.7 Mg C ha^{-1}) can be calculated, if we assume a SOC change to the level before manipulation. The CO_2-C sink is reduced to 140 g C m^{-2} (1.4 Mg C ha^{-1}), if the topsoil reaches SK0.

3.1 Changes of physical and chemical topsoil properties due to the manipulation

No differentiation of topsoil properties between upper and lower topsoil could be detected after manipulation, neither for plot 11, nor for plot 10 (Fig. 4). This indicates a thorough mixing of the applied soil material with the Ap horizons. Soil textures of Ap horizons are very similar in all 4 plots (9, 10, 11, and 12). Even the supply of clay-enriched subsoil material at plot 11 did not lead to a considerable change of the particle size composition (Table 4, Table 5). Textural classes of Sl3 to Sl4 [30] are still prevalent.

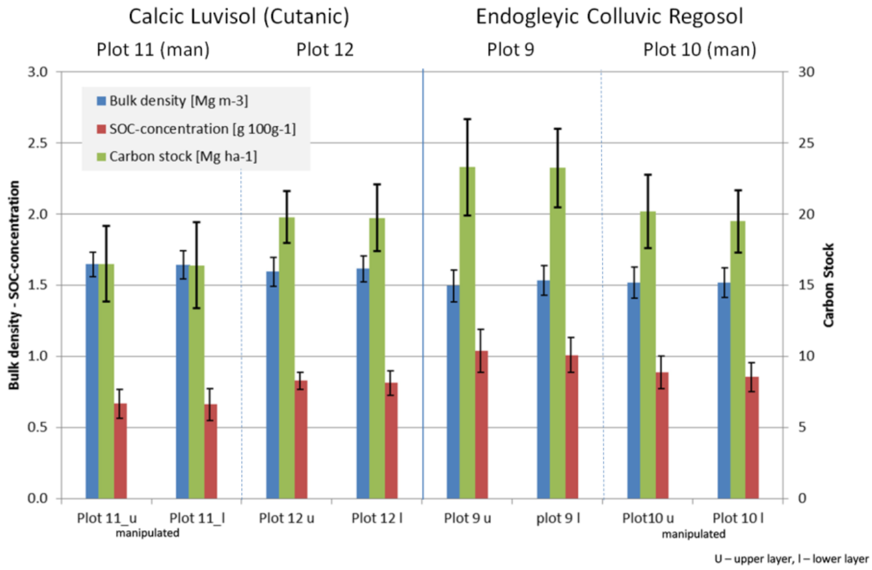

FIGURE 4. MEAN AND STANDARD DEVIATION OF BULK DENSITIES, SOC-CONTENTS AND C STOCKS OF NON- AND MANIPULATED SITES AT CARBOZALF-D (DATA FROM 5M RASTER).

TABLE 5
CLASSIFICATION OF SOC-VALUES IN SOC-TARGET CATEGORIES PRIOR TO THE MANIPULATION (2009) AND AFTER MANIPULATION (2011) FOR MANIPULATED AND NON-MANIPULATED PLOTS IN [%].

	Categories of soil fertility (c.f. Table 3)			
Plot	**[cl+fsi]**	**[cl+fsi] * 0.04 + 0.3**	**[cl+fsi] * 0.04**	**≤ [cl+fsi] * 0.04**
11	**16.3 … 17.8**	**0.95 … 1.01**	**>0.66 … >0.72**	**<0.72 … <0.66**
11 (exam. 2009)			0.82 … 0.85	
11 (exam. 2011)				0.665
12	***13.5 … 14.8***	***0.85 … 0.9***	***>0.56 … >0.61***	***<0.61 … < 0.56***
12 (exam. 2009)		*0.85 … 0.88*		
12 (exam. 2011)			*0.83 … 0.82*	
10	**13.6 … 14.2**	**0.84 … 0.87**	**>0.55 … >0.58**	**<0.58 … < 0.55**
10 (exam. 2009)		1.01 … 1.08		
10 (exam. 2011)			0.87	
9	***14.4 … 14.9***	***0.88 … 0.89***	***>0.58 … >0.59***	***<0.59 … < 0.58***
9 (exam. 2009)		*0.96*	0.85	
9 (exam. 2011)		*1.03*		

In italic – non-manipulated plots; exam.- examined;
cl+fsi- content of clay and fine silt

No substantial difference in average bulk densities of Ap horizons from neighbouring plots could be detected (Fig.4). This can be explained by very similar particle size composition and identical farming practice.

The SOC content in the upper Ap (mean, standard deviation) showed an uniform distribution in the non-manipulated plots (9, 12) and the manipulated plots (10, 11) (Fig. 3, 4). This indicates a complete incorporation of the Bt mass in plot 11 and of Ap mass from plot 11 to plot 10. The incorporation of clay-enriched subsoil material into the Ap at plot 11 led to a dilution of SOC in the topsoil (Table 5). The content and stock of organic carbon were reduced from 0.84% to 0.67% or from 4.0 kg m^{-2} to 3.2 kg m^{-2}, respectively. The admixture of topsoil material from plot 11 to plot 10 also led to a SOC dilution in the Ap at plot 10 (Table 4). The content and stock of organic carbon were reduced from 1.04% to 0.87%, or from 5 kg m^{-2} to 4.2 kg m^{-2}, respectively.

The geostatistical analysis showed no spatial dependence of bulk density, SOC content, and SOC stock in plots 10 and 11 (manipulated) and plot 12 (not manipulated) (Fig. 5). This was intended by our plot arrangement according to a spatial top-down procedure [33]. One exception is plot 9 (not manipulated) with a range of nearly 20 m, which is caused by the geometry of a hollow, hence a gradual sloping towards the lowermost position.

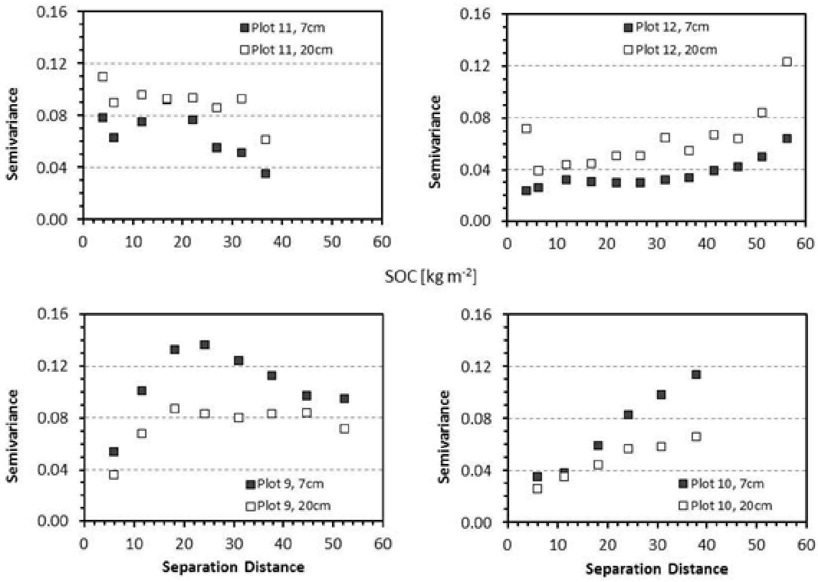

FIGURE 5. SEMIVARIOGRAMS OF SOC FROM PLOTS 9-12.

One a priori concern was about the accessibility of the admixed Bt (in Ap, plot 11) to plant roots, i.e. the ultimate carbon source. Although distinct domains of Bt can be identified in undisturbed cores (Fig. 6, left) the porosity of these is higher compared to the surrounding matrix of (former) Ap (Fig. 6, right). From this observation we conclude the assumption of accessible mineral surfaces to fresh plant C input to be valid.

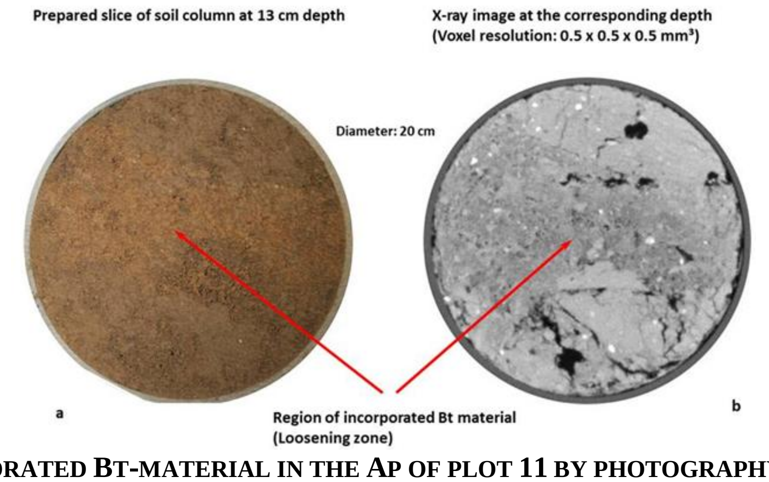

FIGURE 6. INCORPORATED BT-MATERIAL IN THE AP OF PLOT 11 BY PHOTOGRAPHY (LEFT, BT IN RED-BROWN) AND X-RAY IMAGING (CT, RIGHT: BT IN DARKER GRAY)

IV. DISCUSSION

The manipulation experiment in “erosion / aggradation” is a basis for subsequent examinations. The intended changes could be achieved (cf. before). The Ap material (plot 10) and Bt material (plot 11) added to the manipulation plots were applied to the surface in balanced quality and was incorporated into the topsoil. Now conditions were provided for the onset of long-term processes in generating new macrostructures through physical, chemical and biological processes [21].

Possible CO_2 emissions during erosion processes have been depicted in the reference literature. Hu and Kuhn [34] mention a possible selective transport of C in aggregates of a silty loam textured soil, based on laboratory rain simulations. This was not observed under natural conditions at sandy and loamy sites. Sorting leads to decomposition on a single particle level in the slopes of the Uckermark region. Existing aggregates break apart from drop impact or its cumulative effect during precipitation [35], [36], [37]. The released particles cause an increase of the thin crust layer’s density, ensuing dehydration of the previously sealed soil surface [5], [38]. Studies by [6] indicate that the decomposition of aggregates leads to higher rates of mineralization for SOC in loam and clay, as opposed to sandy soils. He stated that there is a higher share of fine pores that provide protection within the aggregates. Hence, during the erosion process, individual mineralization phases could occur until protection is renewed through the onset of incrustation or burying [39]. Additionally, the current erosion conditions (aggregates in dry, pre-moistened, or moist states) and the precipitation erosivity are important factors alongside the climatic conditions [39], [40], [41]. Thus, smaller erosion events have a minor effect on C transport [8].

The predominant and visible changes caused by transport of soil during soil tillage and soil erosion are those soil conditions that are reflected by plant growth and yield. At the same time, the existing soil heterogeneity increases. Both erosion processes have to be considered. After soil erosion caused by heavy rain, by means of extensive erosion (sheet erosion, rill erosion, gully erosion), in addition to transport by tillage, the farmer tried to achieve an even seedbed via cultivation. Thereby, erosion-caused loss is replaced by the incorporation of reactive subsoil material into the remaining Ap (constant tillage depth). This generally leads to a dilution of the nutrient content in the Ap-horizon and an altered texture. The speed of these alterations under realistic conditions depends on the current precipitation, soil cover, and tillage conditions.

Herzog [9], [42] described the “Müncheberger Dauerversuch” (Müncheberg long-term field trial), which was established in 1962. It features manipulated profile layering for testing the influence of topsoil deepening on plot sizes of 13.5 m². This was done in order to compare normal topsoil to subsoil within the profile and mixed variants, in the context of their influence on yield. Doubling the standard tillage layer (26 cm) by filling with the same soil material to a thickness of 52 cm achieved distinctly increased yield. Whereas tillage of a soil consisting exclusively of subsoil material resulted in distinct yield loss. The C and N concentrations in the subsoil tripled within 14 years to ca. 2/3 of the concentrations in the compared topsoil. This supports the hypothesis that C absorption or storage capacity exists in erosion positions and can be measured from an established experiment. Reuter [21], [43], [44] reports a positive effect on yield and SOC concentration on a “Leptic Podzol” within 20 years under organic fertilization and application of clay-substrate.

TABLE 6
SOC-REGENERATION POSSIBILITIES [47]

Possibility	SOC regeneration kg . m^{-2} C
Dung	0.056
Compost	0.046
Plant residuals/straw	0.08
Digestate	0.05
No till*	0.02 - 0.04
Arable land → grassland*	0.03 – 1
Extensification*	0.05
Grain legumes, seeds	0.016 - 0.024
Agricultural grass	0.06 - 0.08

- described by Fuhrer (2004) in [47]

Table 6 shows how small the annual SOC reproduction potential is. Only through the influence of organic material is the decrease of a deficit between 16 and 80 g m^{-2} possible in erosional plots that are under ongoing agricultural land use. In order to realize this potential, changes in the land use, extensive management, or soil-melioration actions (partial topsoil deepening, mechanized partial mixing of top- and subsoil by rigid or driven tools, blending-in of clay to increase C absorption potential) have to be performed. The results of the manipulation in this research show how fast a decrease in SOC concentration can be achieved. The SOC stock in the soil can be adapted to a higher level by means of an optimal organic and mineral fertilizer within the crop rotation. If further efforts are undertaken, even more SOC storage can be achieved. Nevertheless, this newly stored SOC has a faster decomposition rate when the regular amount of organic fertilizer is increased and in this case we can have potentially negative effects on the ecosystem, e.g. NO_3^--eluviation [18], [21].

An increased SOC status leads to altogether improved soil fertility. For example, the cation exchange capacity, as one of the essential properties determining the ecological soil condition, is improved [21], [36], [45]. The cation exchange capacity is one of the most important properties for complex assessments of ecological soil characteristics, as it determines the nutrient dynamics [21], [46].

The manipulation conducted at our research site provided altered soil conditions, which were required for the simulation of soil transportation caused by erosion or tillage. The initial measurements should contribute to clarify the importance of soil erosion as a source or sink of CO_2 in the climate discussion. Continued monitoring of these research plots will provide additional information about the C dynamics in this type of system.

V. CONCLUSION

Soil and tillage erosion are essential landscape-shaping factors. In the CarboZALF-D experiment the result of those processes was realized more quickly through direct manipulation of the soil. This manipulation specifically changes the soil condition along with physical-chemical properties. The manipulation achieved defined new soil conditions far from steady state. The process initiated by soil tillage/soil erosion - which acts locally in natural systems – has been controlled for these research plots. Thus, at plot scale nearly the same areal conditions exist for the planned studies to answer the question posed at the beginning: Is erosion acting as a CO_2 source or sink?

Both manipulated plots have the ability to return to the initial state of carbon content (= sequestration potential). A reduction of the period and an acceleration of those processes can possibly be achieved through a change in management (extensification, humus supply…). Actions in the system through the tillage erosion with constant rates and unforeseeable sudden changes by water erosion are to be considered.

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