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Soil organic carbon stocks in hedge-banks as agricultural marginal areas

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1 Zusammenfassung

Kohlenstoffinventare sind ein wichtiges Instrument, um Klimabilanzen auf verschiedener Ebene zu erstellen. Hinsichtlich der Diskussion zur Berücksichtigung von Landwirtschaft im Emissionshandel dient die Erfassung von natürlichen Kohlenstoffsenken auf Wirtschafts- und Randflächen. In dieser Arbeit wurde für den Versuchsbetrieb des Instituts für Ökologischen Landbau in Trenthorst, Schleswig-Holstein ein Bodenkohlenstoffinventar erstellt. Besondere Beachtung fanden die landschaftsprägenden Wallhecken, die größere Mengen an Boden anreichern. Diese wurden bislang nicht in Klimabewertungen mit einbezogen. Bodenuntersuchungen und Flächenbestimmungen erfolgten an Acker, Grünland, Wald und Wallhecken. Es fanden zwei Ansätze zur Erfassung des Wallheckenbodenvolumens statt. Ergebnisse wurden für erste Einschätzungen auf Schleswig-Holstein extrapoliert.

Die Wallhecken des Betriebes nehmen 1,8 % der Wirtschafts- und Randflächen ein und erreichen bei einem durchschnittlichen C_{org}-Gehalt von 2,1 % einen Mengenanteil von 2,1 % des Kohlenstoffinventars. Das Gesamte Kohlenstoffinventar der 592 ha beträgt 83 kt C_{org}. Im Schnitt liegen die C_{org}-Gehalte bis 0,6 m Tiefe im Acker bei 98 t ha^{-1}, im Wald bei 123 t ha^{-1}, in der Wallhecke bei 163 t ha^{-1} und im Grünland bei 296 t ha^{-1}. Das Kohlenstoffinventar der Wallhecken Schleswig-Holsteins wird auf 2,2 Mt C_{org} geschätzt.

Die Ergebnisse deuten an, dass die weitere Etablierung und Nutzung von Wallhecken ein für den Klimaschutz förderfähiges Instrument sind, wobei der energetische Nutzen der Wallheckenaufwüchse eine bedeutende Rolle spielt.

2 Abstract

In comparison to fields and forest, soils in hedge-banks represent a carbon sink with higher capacity. As described, this sink can play an important role in the evaluation of the carbon footprint of an agricultural holding. In this experiment, the hedge-bank body held a captured amount of SOC of 2.1% of the area surveyed. Its sink capacity per area was only surpassed by pasture, which has a $SOC_{0.6m}$ content which appears unusually high.

The amount of SOC sequestered by hedge-banks across Schleswig-Holstein constitutes a potential that is worth maintaining. It has to be considered that the standing stock of carbon above ground is usually higher than in the equivalent land use without trees (Smith et al. 2007). Therefore the continuous value of hedges has to be seen in use of woodchips as fuel. It will be of increasing economic and climatic importance and must be seen as a positive fact for the preservation of hedge-banks (Baral and Guha 2004). Eggersglüß (2005) calculates the hedge-bank wood potential of Schleswig-Holstein equivalent to 20 - 40 million litres of heating fuel oil annually at 15 year harvest intervals. Regarding the inclusion of agriculture in

emission trading, further establishment and utilisation of hedge-banks may be an eligible instrument.

There is a need to further investigate (i) the lower depths of hedge-banks, (ii) how representative sampling at the crest of a hedge-bank is, (iii) the SOC reproduction performance in hedge-bank soil, (iv) the effects of the areas surrounding the hedge-banks on the SOC content, and (v) the integration of additional forest structures into agriculturally used areas.

3 Introduction and Objectives

In 2006 the agricultural sector produced 6.3 % or 63.5 Mt CO_2 eq (excluding land use, land use change and forestry emissions) (UBA 2008), of the total man-made greenhouse gas emissions in Germany. More than half of these emissions originate from moorland drainage, bovine digestion, agronomic use of pastures and use of mineral fertilisers (Wegener 2006). Apart from the substitution of fossil fuels and improving efficiency in agricultural systems, the promotion of natural carbon sinks is another method of reducing emissions (Lal et al. 2007, Tomlison and Milne 2006). A considerable amount of carbon can be captured in organic form by setting up long-term agricultural and forestry carbon sinks (Smith et al. 2007). In Sect 3 Par 3 of the Kyōto Protocol climate framework agreement the limited option of biological sources and sinks is given to offset changes in land and forestry use against reduction commitments. However, Sect 3 Par 4 leaves the option to integrate additional ways of capturing carbon (UN 1998).

World-wide approximately 2,500 Gt of carbon are soil-bound, approximately 60 % of it in the form of organic carbon (SOC) and 40 % in the form of inorganic carbon (SIC). SOC represents twice the amount of atmospheric carbon and demonstrates the capacity of soil to capture or release carbon. Up to a depth of 1 m the amount of stored SOC reaches 30 t ha^{-1} in arid climates and 800 t ha^{-1} in cold climates, with the majority captured in densities between 50 – 150 t ha^{-1} SOC (Lal 2004a and 2004b).

Hedge-banks, of which there are 45,000 km in Schleswig-Holstein (LANU Schleswig-Holstein, 2006) are a significant countryside feature. Generally man-made, they consist of walls overgrown with shrubs and trees that function or functioned as border demarcations of fields, pastures or roads. Their ecological attributes include protection from aeolian erosion, increasing biodiversity and knock-on effects (Müller 2006). Growth from hedge-banks is also directly used as a heating fuel (Holsteiner 2008, Mues 2008). The banks mostly consist of soil, reaching an average height of 1.2 m with a base width of 2 m (Müller 2006). Hedge-banks are legally protected by law (§15b LNatSchG Sch.-H.). Among other things the law recommends setting the cutting intervals at 10 to 15 years, while they may not fall below the limit of 10 years.

The assumption is that hedge-banks store a considerable, hitherto unknown quantity of SOC which must be considered when calculating the carbon footprint of an agricultural holding. This paper aims to do a quantitative evaluation of SOC on an agricultural holding based on the agricultural experimental farm operated by the Institute of Organic Farming (OEL) in Trenthorst, Schleswig-Holstein. The aim is to evaluate the role of the above mentioned marginal areas within the overall carbon footprint of a holding. This will form the basis of preliminary estimates of SOC in hedge-banks.

4 Materials and Methods

Using geo-information system software ArcMap (Version 8.2, by ESRI) the field, pasture, forest and hedge-border area of the farm was determined.

Between April and June 5, soil samples were taken from 4 locations representing the soil types and plant species mapping using a Pürckhauer soil corer from depths of 0 - 0.3 m and 0.3 – 0.6 m. In the hedge-banks these were taken from the crest. The soil samples were analysed on their carbon content using an elemental analyser (EuroEA 3000, by HEKAtech) and tested for their humidity. The mean average was calculated for each location with data out of the interquintile range $Q_{.2}$-$Q_{.8}$ discarded as outliers. Prior to analysis a carbonate test was conducted using 10% HCl and samples with a positive result discarded.

To determine the oven-dry density (ODD) 3 undisturbed vertical soil samples each were taken from depths of 5-10 cm, 15-20 cm and 25-30 cm using a 100 cm^{-3} core cutter from a stepped test pit. By drying the samples to the equilibrium constant at 105°C the dry matter was determined. ODD was not determined for lower soil layers. Assuming that lower soil levels have a higher density due to lower biospheric penetration, in the following the ODD for the 0 – 0.3 m layer will be used for calculations of the 0.3 - 0.6 m depth for first estimates and is therefore underestimated.

Soil Type	Cambisol, Luvisol
Soil texture	sL, L, tL
Soil taxation points	ø 53
Forest Type	Mixed beech
Annual temperature (long term mean)	8.7°C
Annual rainfall (long term mean)	735 mm

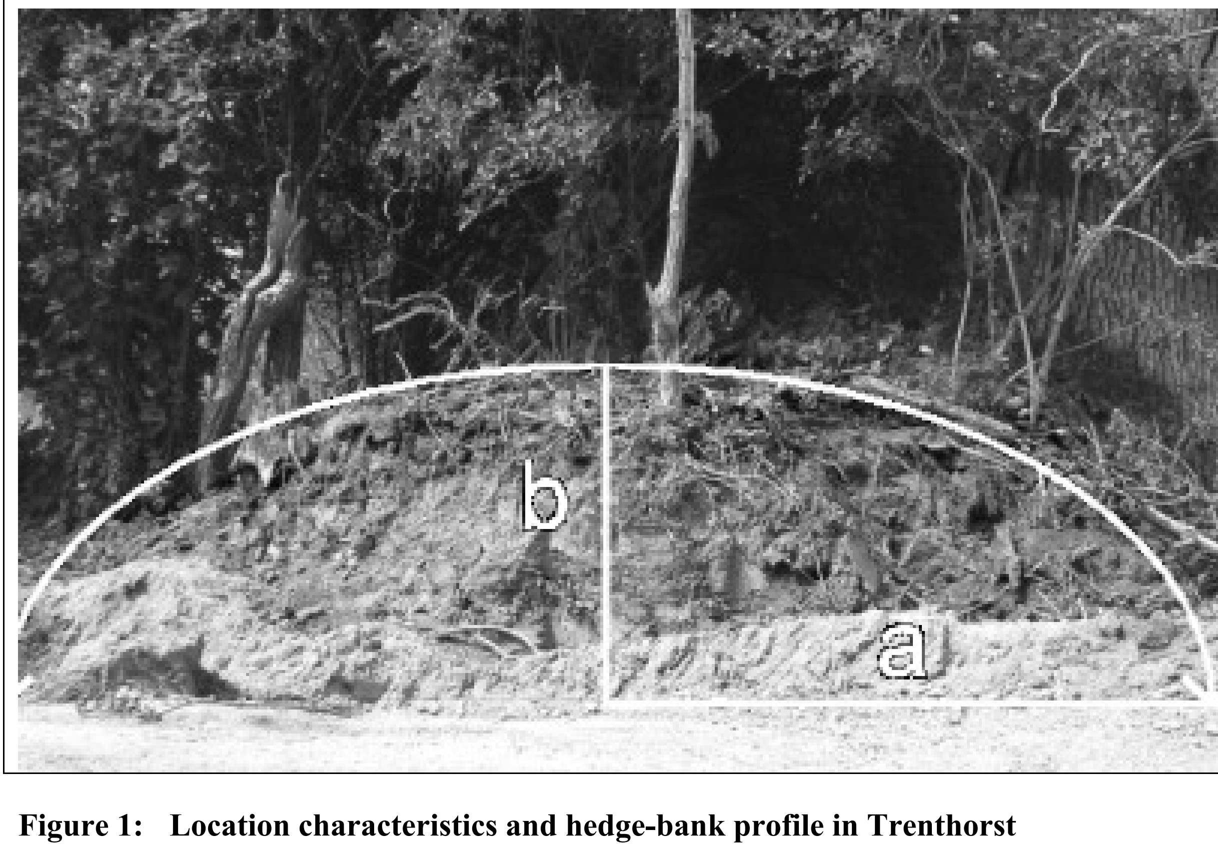

Figure 1: Location characteristics and hedge-bank profile in Trenthorst

The hedge-bank body volume is the accumulation of soil around the hedge-bank which is above the surrounding ground level. To calculate the bank body volume, the base width and height of a number of hedge-banks (n = 20) was measured. The cross section of the bank body is visually delineated as an elevation in the ground relief, with the base width being the distance of these delineations. Its height is the vertical distance between the outer edge of the hedge-bank base and the height of the crest. To calculate the cross-section surface area of the bank body an elliptical shape split lengthwise is assumed for geometrical purposes (see figure 1).

$$A_{Hedge-bank} = \frac{1}{2}\pi\, a\, b$$

a = semi-major axis (half the base width) and b = semi-minor axis (height)

In the following the sum of the field, pasture, forest and hedge-bank area is referred to as Economic and Marginal Area (EMA).

5 Results and Discussion

The farm's hedge-banks examined had an average base width of 3.9 m (SD = 0.85) and an average height of 0.6 m (SD = 0.15). In terms of volume this is equivalent to a cuboid 0.47 m tall. The cumulative hedge-bank length is 28 km, which is equal to an area of 10.9 ha, representing 1.8 % of the EMA (592 ha).

As Table 1 illustrates, the hedge-bank body averages 2.1 % SOC, decreasing with increasing depth. In relation to the length this equates to a length of 49.6t km^{-1} or an area of 127 t ha^{-1} of stored SOC. This means the hedge-bank body amounts to 1.4 kt SOC or 5.1 kt CO_2 eq of sunk carbon across the entire EMA. According to the methane emission potential of one dairy cow and from their manure with storage measured with 3,500 kg CO_{2eq} per year (Külling et al. 2002) the accumulated SOC in the hedge banks at OEL would equal the emissions of 14 dairy cows over 100 years.

Table 1: Area, ODD, SOC content, SD (in brackets), total SOC of the hedge-bank body at Trenthorst

Area	ha	11
Area	% EMA	1.8
ODD	g cm^{-3}	1.28
SOC 0 - 0.3 m	%	2.8 (0.3)
SOC 0.3 m - 0.6 m	%	1.5 (0.4)
SOC average	%	2.1
SOC cuboid 0,47m	t	1,401
SOC (hedge bank)	t ha^{-1}	127

The collected data allows a preliminary estimate of the total hedge-bank body of Schleswig-Holstein, whose 9,000 ha of hedge-bank (2 m wide) represent 1.0 % of the agriculturally used area. Calculated with 45,000 km hedges with OEL conditions, this would represent 2.2 Mt captured SOC or 8.2 Mt CO_{2eq} and this would equal the methane emission potential of all of Schleswig-Holstein's 360,000 dairy cows (November 2007, Statistikamt Nord 2008) over 6.5 years. A conservative estimate (highly reduced SOC content: 1.5 %, hedge-bank body in a worse condition: base width and height -20 %) equates this to 0.7 Mt SOC or 2.4 Mt CO_2 eq.

The method described to quantify the volume of the hedge-bank body described the bank body as a supraplanar element above the surrounding surface level. A prerequisite for this is a sampling depth of the full wall height. Another possibility of describing the bank body is to sample it across its width and across the full sampling depth. This ignores the tendency of a bank to accumulate soil. This approach allows a direct comparison with areas of equivalent sampling depth (Figure 2).

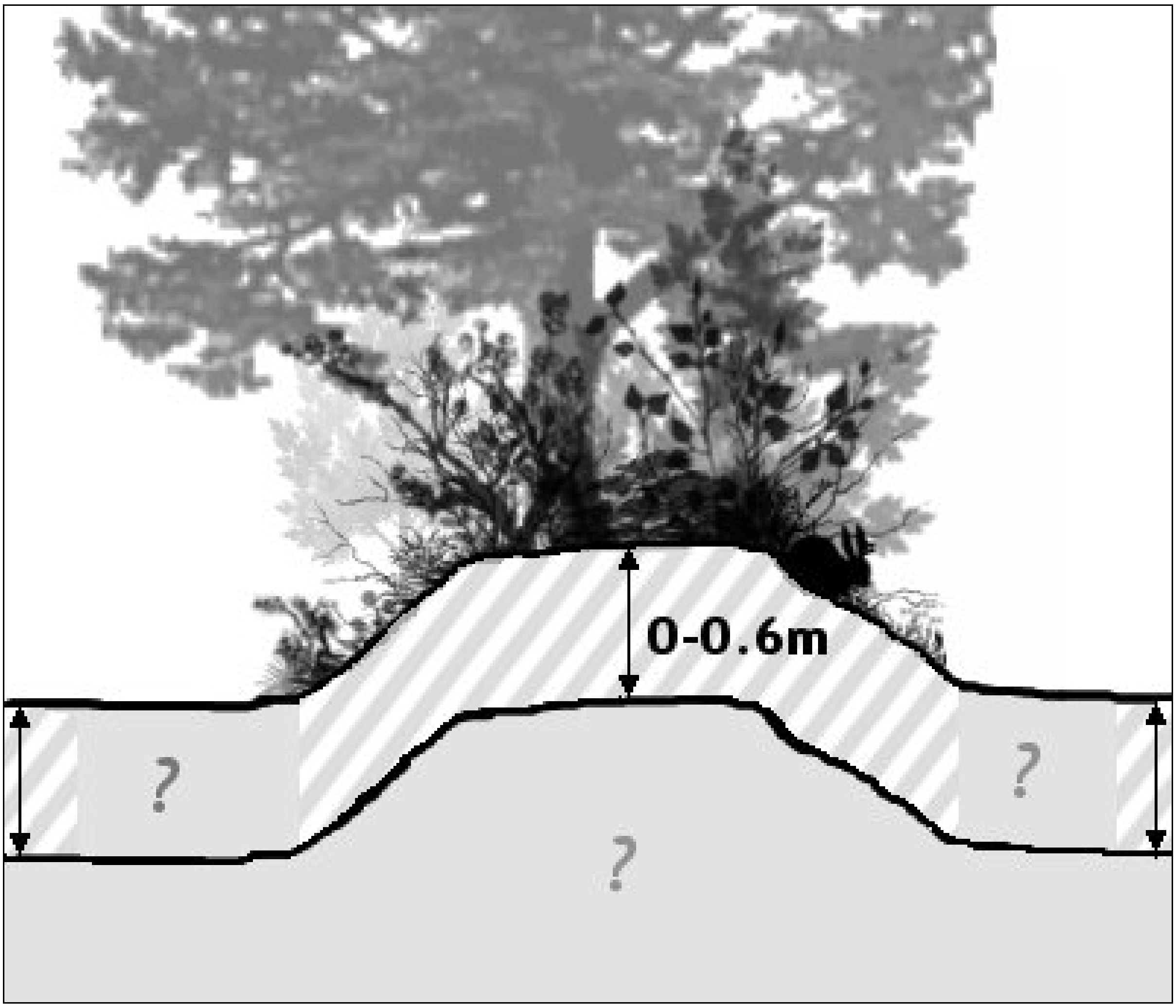

Figure 2: Depiction of described and unsurveyed soil areas of hedge-banks and adjacent sites

Because these are no data regarding the soil composition below the sampled areas underneath the bank body, it is recommended that future investigations take additional soil samples from the outside quarter of the bank body. In the following preliminary area comparison, the hedge-bank bodies are compared with field, pasture and forestry data assuming an equal sampling depth of 0.6 m.

The total captured SOC of the EMA (Table 2) is 83.2 kt. As expected, the amount of captured SOC of pasture, hedge-banks and forest is above that of fields. It is worth noting that in this experiment, pasture has the highest amount of captured SOC. The comparative ratio of captured $SOC_{0.6\ m}$ per area unit is 1.7 : 1 : 1.3 : 3 for hedge-banks, fields, forest and pasture. The share of the hedge-banks on the total SOC inventory is 2.1 %.

Limitations in this study can be found in that the amounts of stones within the soil were not considered. Furthermore, a small sample range was used to extrapolate the SOC of the hedge-banks of Schleswig-Holstein.

Table 2: Area, ODD, SOC content and total SOC of the EMA at Trenthorst and published data for comparative purposes

		Hedge-bank	Field	Forest	Pasture
Area	ha	11	366	104	111
ODD	g cm^{-3}	1.28	1.56	1.06	1.46
SOC 0 - 0.6m	%	2.1	1.1	1.9	3.4
SOC 0 - 0.6 m	t	1,782	35,881	12,829	32,870
SOC 0 - 0.3 m	t ha^{-1}	106	68	94	125
SOC 0 - 0.6 m	t ha^{-1}	163	98	123	296
SOC 0 - 0.3 m	t ha^{-1}	-	80[c]	90[a]	236[b]
SOC 0 - 0.5 m	t ha^{-1}	-	68-83[d]	86[d], 126[e]	-
SOC 0 - 1 m	t ha^{-1}	-	106±63[f]	-	150±101[f]

[a] Temperate, Europe (Kauppi et al. 1992)
[b] Temperate, global (WBGU 1998)
[c] (Houghton et al. 2001)
[d] para-brown soil, Schleswig-Holstein (Bayer & Blume 1989)
[e] Beech, age 57 - 67, value includes Litter, Lower Saxony (Kriebitzsch 2005, 2008)
[f] Baden-Württemberg (Neufeldt 2005)

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