Nitrogen dynamics in deep ploughed soils of North Germany

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Contents

- Background
- Methods
- Results
- Conclusions

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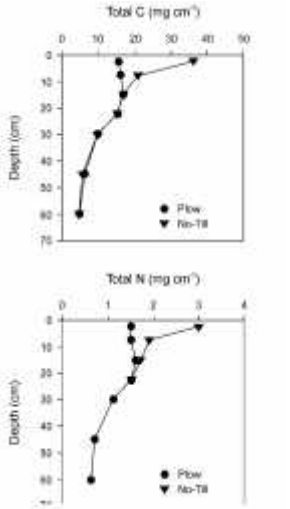
Background

- Conservation tillage may slightly increase soil organic carbon (SOC) and total nitrogen stocks, particularly in the upper part of the former Ap

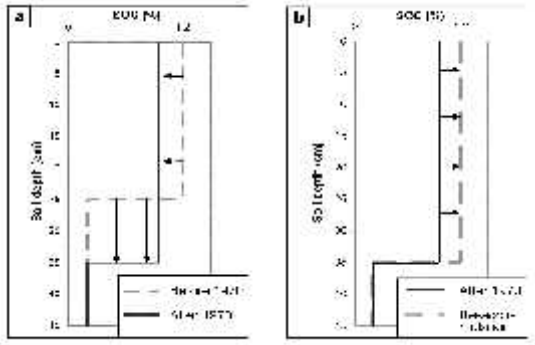
(SIX et al., 1999; STOCKFISCH et al., 1999; WANDER & BIDART, 2000; CARTER, 2005; NIEDER & BENBI, 2008; KAISER et al., 2014)

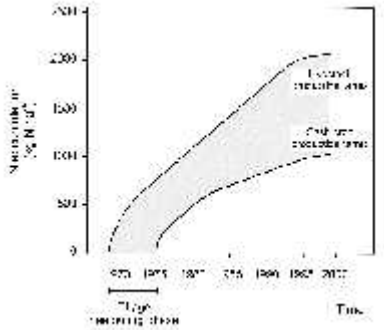
Tillage treatment effects on SOC and total N within the upper 60 cm of a silt loam following 12 years of continuous corn (NIEDER & BENBI, 2008)



- Long-term SOC and total N accumulation after deepening of plough layers

(NIEDER & RICHTER 1986, 1991 & 2000; NIEDER & BENBI, 2008)

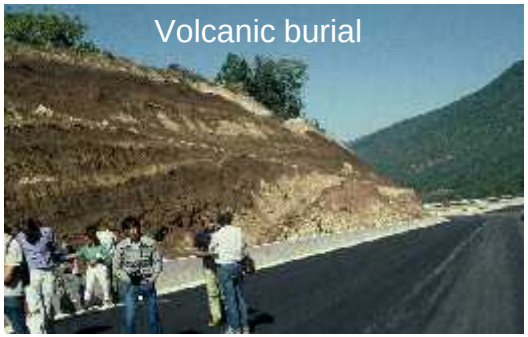




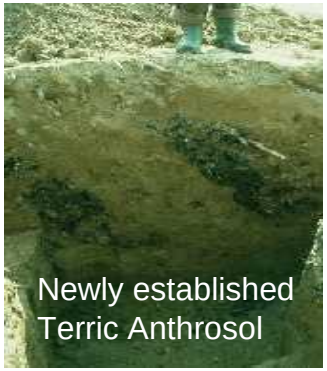
N accumulation after deepening the tillage from <25 to >35 cm in Germany (NIEDER & BENBI, 2008)

Background

- Soil organic matter (SOM) burial causes long-term conservation of SOC and Ntot
  (VAN OOST et al. 2012; HOFFMANN et al. 2013; JOHNSON 2014; CHAOPRICHA & MARÍN-SPIOTTA 2014)



- Effect of deep ploughing (>60 cm) on C and N dynamics?



Background

Reasons for deep ploughing

Since the late 19th century until the 1960s
- Peat cultivation
- Enlarging the rooting zone of mineral soils
- Improving soil structure in loess-derived Luvisols
- Breaking hardpans of sandy Podzols (B horizons)
- Melioration of Stagnosols


Modern deep plough
moved by 3 carterpillars

Less common since the 1970s

Current uses (only small areas)
- Breaking through of ploughing-induced hardpans
- Site preparation for afforestation

Background

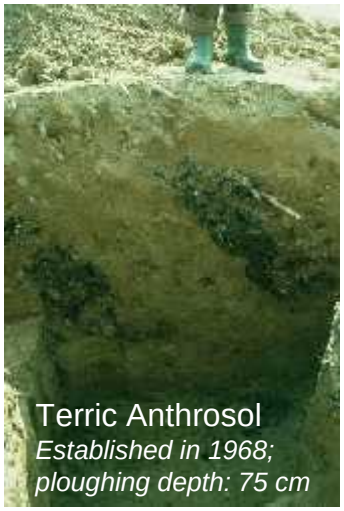
Deep ploughing

- Drastic tillage operation
- Performed only once
- A number of field trials in Germany in the 1960s and the 1970s

Main characteristics:

- Dilution of SOC and Nt in the new Ap horizon

- Slanted Ap and B horizon stripes in the subsoil



Terric Anthrosol
Established in 1968; ploughing depth: 75 cm

Terric Anthrosol
46 years after deep ploughing

Reference soil:
Dystric Cambisol

Objectives of this study

- Investigate the N stock changes since the deep ploughing operation in the soil profile
- Study net N mineralization potential of buried Ap material vs. surface Ap horizons
- Quantify nitrification potential of buried Ap material vs. surface Ap horizons

Methods

Sampling area

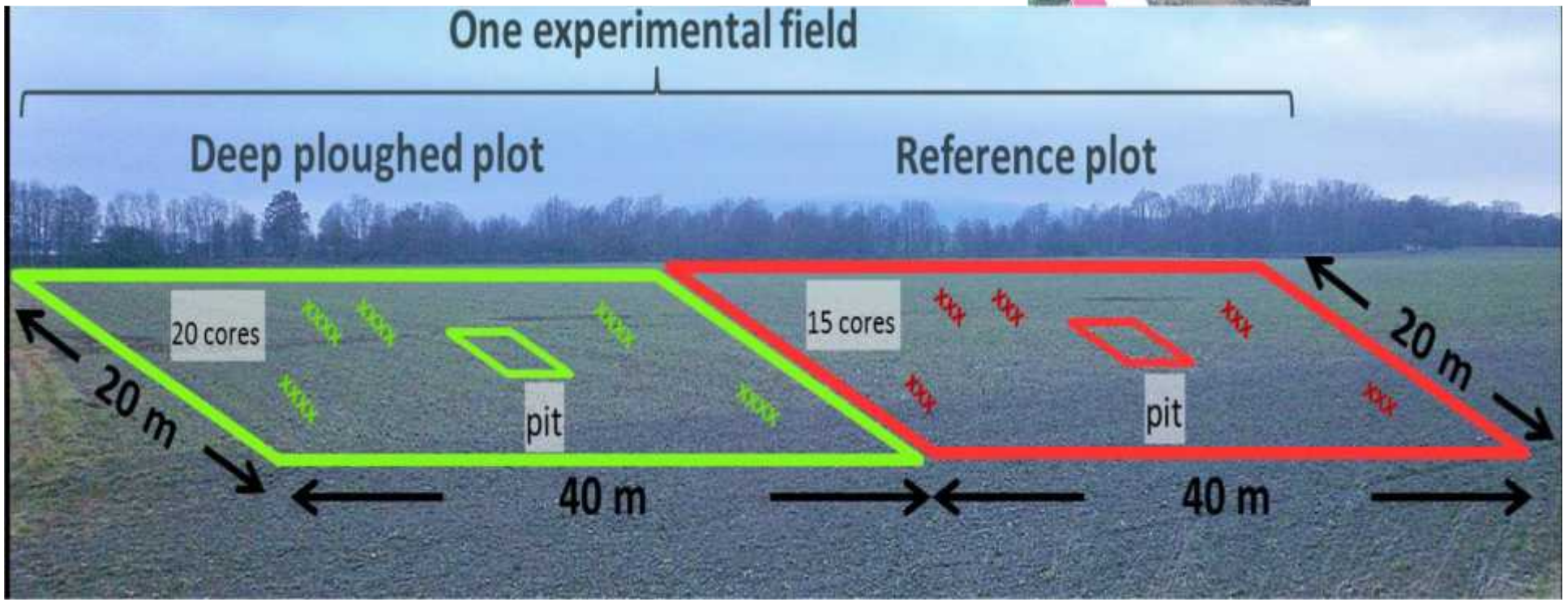
Methods

Sampling locations

Years of sampling: 2013/14
Total number of sites: 10
5 sites with sandy soils
5 sites with loess soils

Methods

Soil sampling scheme



Soil sampling: 35 randomly distributed soil cores down to 100 cm depth and from 2 pits down to 150 cm depth

Methods

Site description and soil characteristics

Location	Short form	Parent material	Soil unit*	Texture	pH** ($CaCl_2$)	Total N** (%)	Deep ploughing depth in cm (year)
Ahlhorn	AH	Pleistocene sand	Spodic Cambisol	Sand	5.6	0.16	90 (1968)
Banteln	BT	Loess	Haplic Luvisol	Silty loam	6.5	0.12	85 (1965)
Drüber	DB	„	„ „	“ “	6.8	0.12	87 (1966)
Essemühle	EM	Pleistocene sand	Dystric Cambisol	Sand	4.6	0.09	75 (1968)
Eickenrode	ER	„ „	Gleyic Cambisol	“	5.8	0.13	65 (1968)
Elze	EZ	„ „	Dystric Cambisol	“	5.4	0.09	55 (1968)
Hemmelsberg	HB	„ „	Haplic Podzol	“	5.4	0.18	80 (1978)
Halchter	HT	Loess	Haplic Luvisol	Silty loam	6.3	0.10	70 (1966)
Salzgitter	SZ	„	„ „	“ “	6.8	0.15	90 (1966)
Warberg	WB	„	Stagnic Luvisol	“ “	5.6	0.09	65 (1966)

*According to WRB (IUSS Working Group, 2007); **pH and total N in Ap horizons of the reference soils

- Deep ploughing in experimental fields was carried out about 35-50 years before sampling
- Deep ploughing depth ranged between 55 and 90 cm

Methods

Soil analyses

Soil pH: In 0.01 M $CaCl_2$ using a glass electrode
Soil texture: Sedimentation method
Total C and N: Elemental analyser via dry combustion
Soil bulk density: Undisturbed samples were dried at 105°C to constant mass and weighed

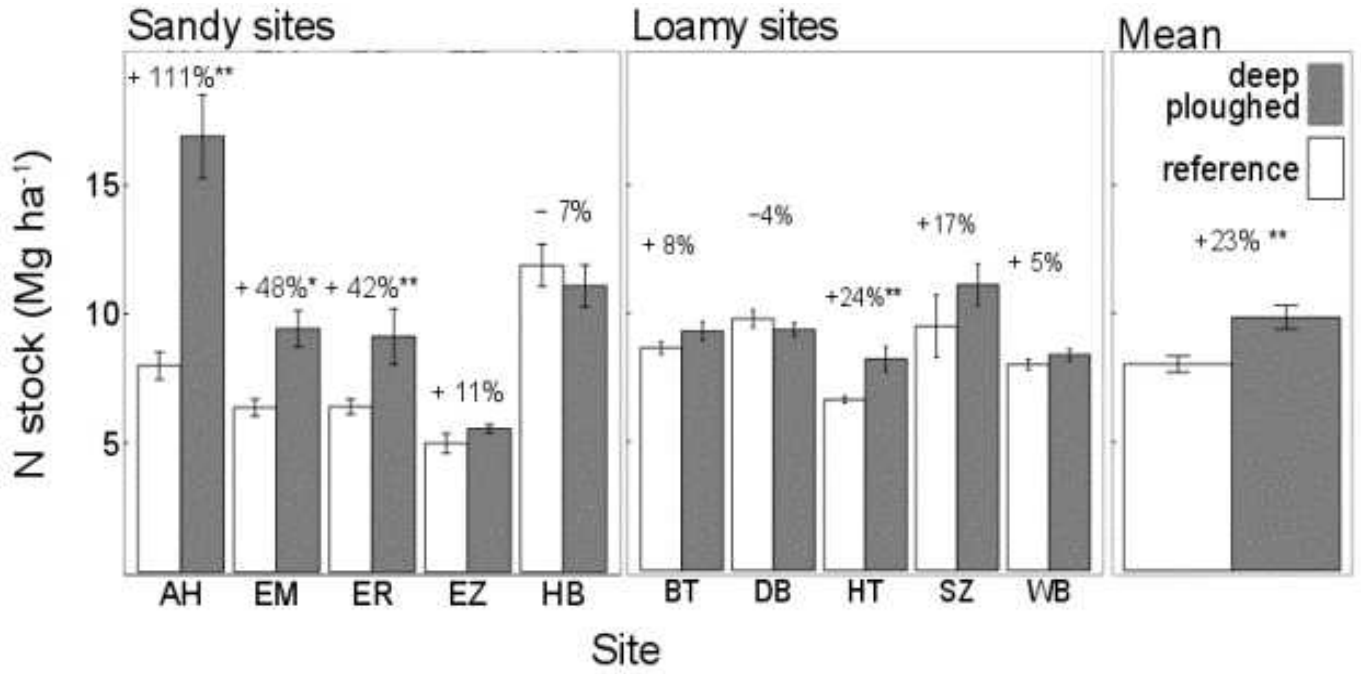
Incubation experiment on nitrogen mineralization (35°)
(Stanford & Smith 1972, Nordmeyer & Richter 1985)

day 1, 3, 7…….. 177

Experiment on nitrification (25°) following ammonium fertilizer application (100 µg $NH4^+$-N g^{-1} soil);

day 1, 3, 5, 7

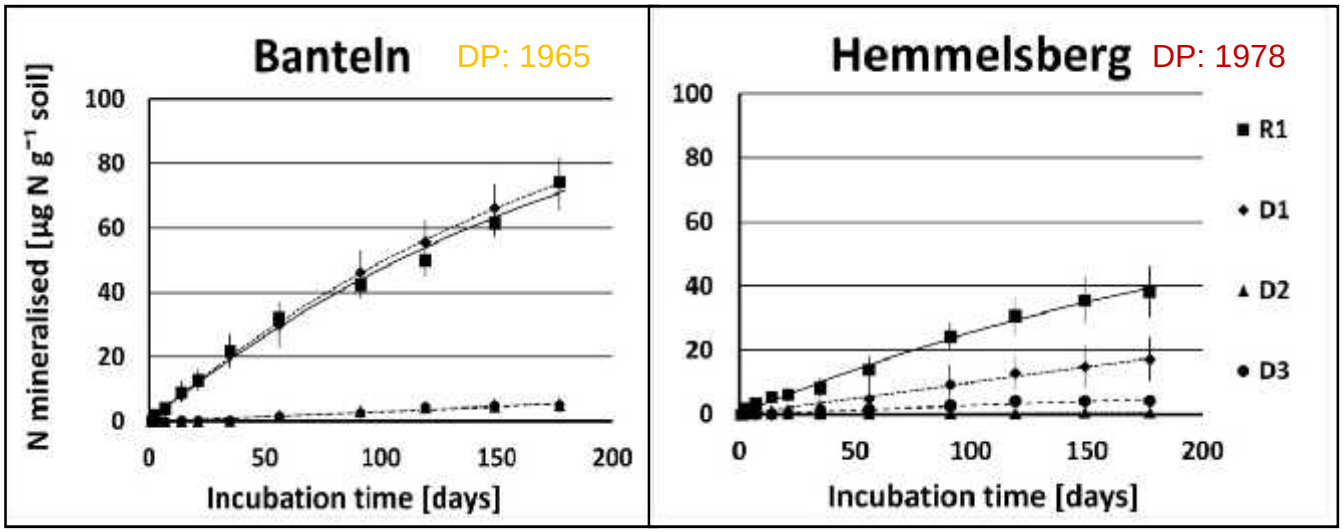
Results



N stock changes after 45 years (mean of 10 sampling sites) in deep ploughed vs. reference soils

- Deep ploughing resulted in a mean N accumulation (0-100 cm) of 1.8±0.4 Mg ha^{-1} (mean increase by 23%)
- This is equal to a mean N accumulation of 41 kg N ha^{-1} year^{-1}
- Only two locations (HB and DB) showed slightly negative N balances

Results



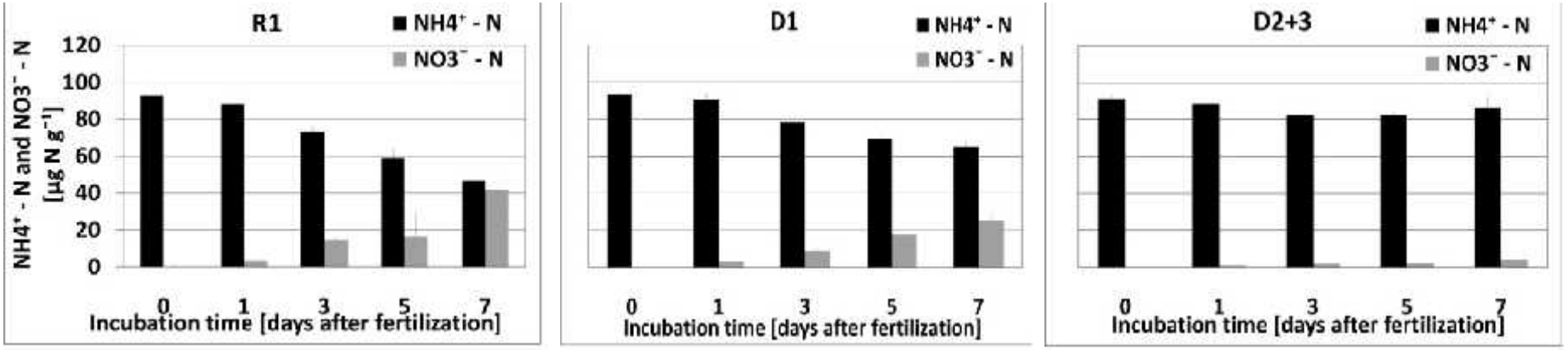
Courses of N mineralization in soil samples from Banteln (Haplic Luvisol) and Hemmelsberg (Haplic Podzol)
Measured and estimated (according to a first-order single exponential model) values are given with dots and curves, resp.

- R1: Ap of reference soil
- D1: Ap of deep ploughed soil
- D2 and D3: upper and lower part of the buried Ap

Cumulative N mineralization (in kg ha^{-1}) until day 177

Site	R1	D1	D2	D3
Banteln	356.0	376.8	16.9	16.6
Hemmelsberg	250.5	97.3	2.5	14.3

Results



Results from the nitrification experiment with fertilization of the sampling site Hemmelsberg

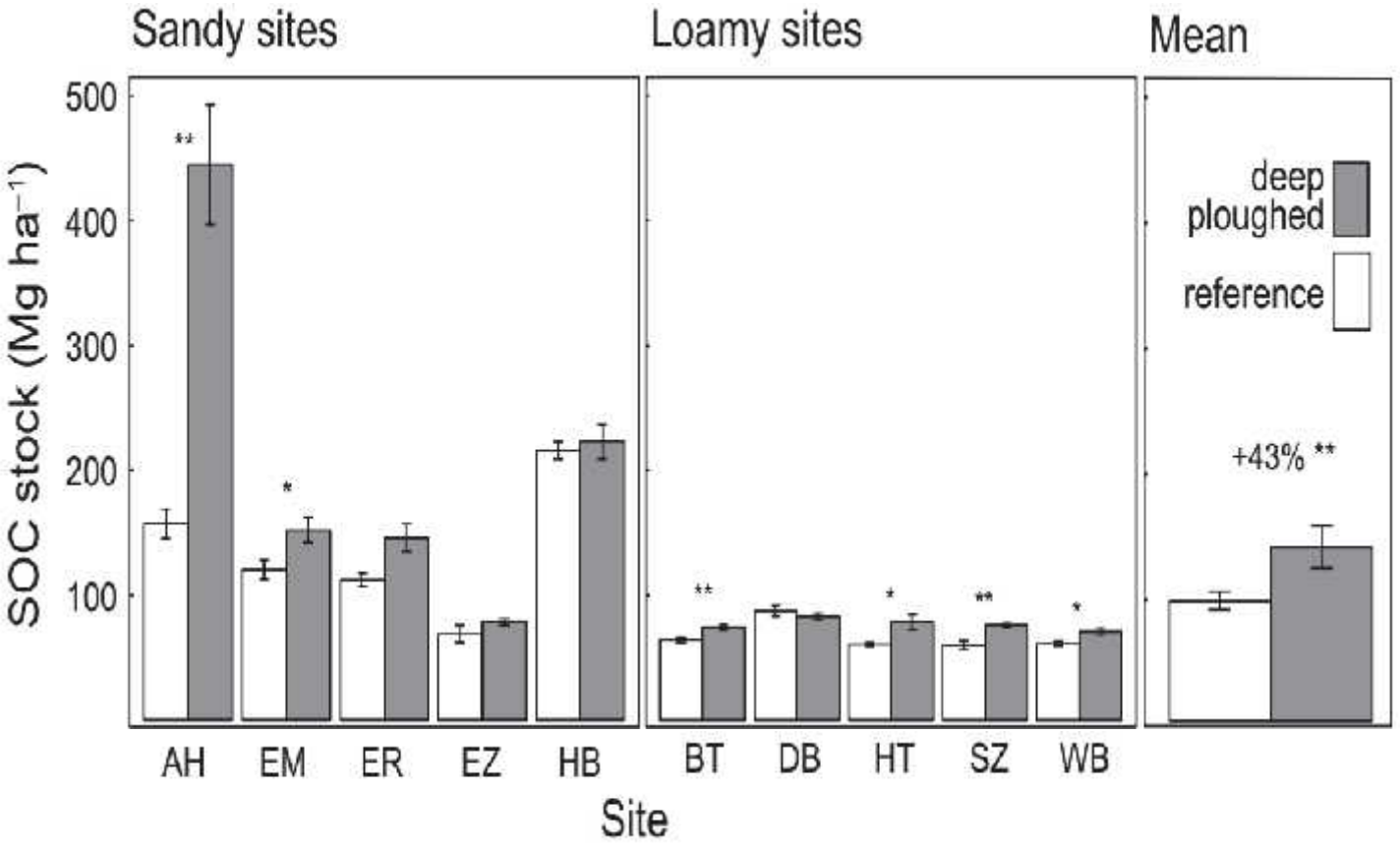
- R1: Ap of reference soil
- D1: Ap of deep ploughed soil
- D2+D3: Mixture of upper and lower parts of the buried Ap

Conclusions

- Deep ploughing may offer a significant potential for long-term N (and C) accumulation through
  - burial of high amounts of SOM associated with long-term N (and C) preservation
  - N (and C) immobilization in newly formed SOM in the new Ap horizon
- The expected SOM equilibrium may be attained over a period longer than 4-5 decades
- Extremely low N mineralization potentials and nitrification capacities in the buried Ap material may be drawn back to
  - less available C as energy source
  - lower microbial biomass and activity
  - N immobilization in stable SOM fractions

For more information see Poster 25

Thank you!



SOC stocks (100 cm depth) of deep ploughed soils vs reference plots. Sites have been deep ploughed 35-50 years ago to a maximum depth of 90 cm (Alcántara et al., 2016)