Nitrogen dynamics in deep ploughed soils of North Germany

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Introduction

Deep ploughing (DP) is a drastic tillage operation which is performed only once. DP has been promoted in Germany until the 1970s as a measure of breaking hardpans of sandy Podzols, improving soil structure and increasing water infiltration in loess-derived Luvisols (Alcántara et al., 2016). The main characteristics of deep ploughed soils are dilution of soil organic matter (SOM) in the "new" Ap horizon (Fig. 1) and coexistence of slanted Ap and B horizon stripes in the subsoil (Figs. 1 and 2).

Fig. 1: Terric Anthrosol
directly after deep ploughing in 1968; ploughing depth: 75 cm

Fig. 2: Terric Anthrosol
46 years after deep ploughing

Specific objectives:
1) Investigate N stock changes in the whole soil profile
2) Quantify net N mineralization potential of buried Ap horizon material vs. surface Ap horizons
3) Estimate nitrification capacity of DP soils and their reference soils

Methods

Soil sampling

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

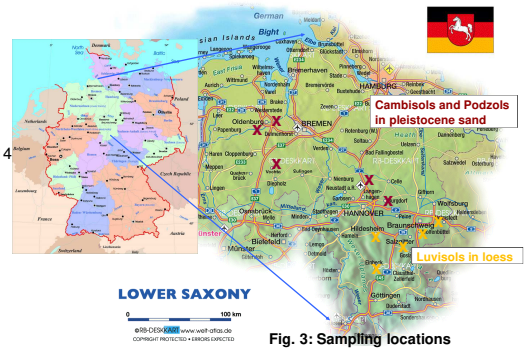


Fig. 3: Sampling locations

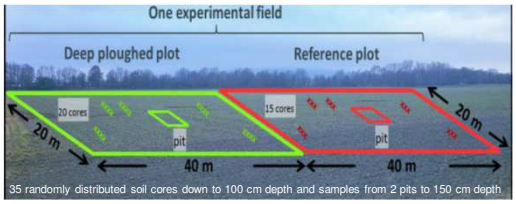


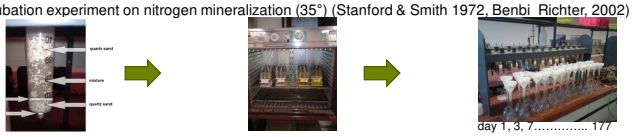
Fig. 4: Soil sampling scheme

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

Laboratory experiments

1) Incubation experiment on nitrogen mineralization (35°) (Stanford & Smith 1972, Benbi Richter, 2002)



2) Experiment on nitrification (25°) following ammonium fertilizer application (100 µg NH_4^+-N g^{-1} soil)

Results

Tab. 1: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

N stock changes

- Mean N accumulation (0-100 cm) in the deep ploughed soils: 1.8±0.4 Mg ha^{-1}
- Equal to a mean N accumulation of 41 kg N ha^{-1} yr^{-1}
- Only 2 sites showed slightly negative N balances

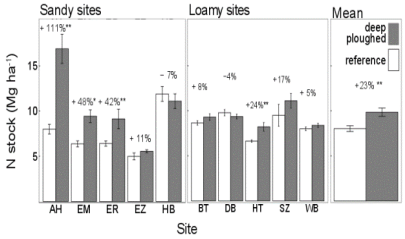


Fig. 5: N stock changes after 45 years in DP vs. reference soils

N mineralization potential

Tab. 2: Cumulative N mineralization (in kg ha^{-1}) until day 177

Site	R1	D1	D2	D3
AH	112.9	41.9	23.8	12.7
BT	356.0	376.8	16.9	16.6
EM	219.9	171.5	13.6	27.5
ER	174.8	161.9	22.3	19.4
HB	250.5	97.3	2.5	14.3
SZ	532.1	635.4	56.4	37.0

R1: Ap of reference soil
D1: Ap of DP soil
D2 and D3: upper and lower parts of the buried Ap

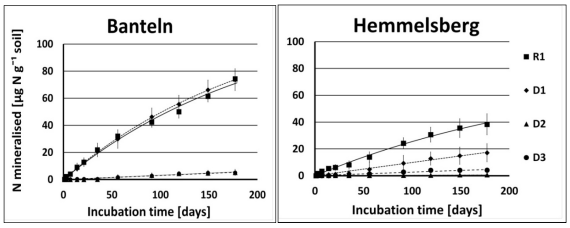


Fig. 6: Courses of N mineralization in soil samples from Banteln (Haplic Luvisol in loess) and Hemmelsberg (Haplic Podzol in Pleistocene sand)
Measured and estimated (according to a first-order single exponential model) values are given with dots and curves, resp.

Nitrification capacity

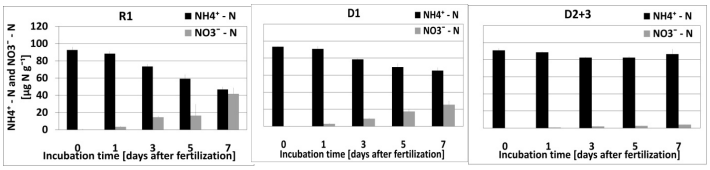


Fig. 7: Results from the nitrification experiment of the sampling site Hemmelsberg

Summary

- Mean N accumulation in DP soils of 1.8±0.4 Mg ha^{-1} is equal to a mean N accumulation of 41 kg N ha^{-1} yr^{-1} (Fig.5)
- N mineralization potential is lower in sandy soils compared to loess soils (Tab. 2 and Fig. 6)
- Both N mineralization (Tab. 2) and nitrification (Fig. 7) capacities are substantially lower in buried Ap material compared to surface Ap horizons of both DP and reference soils

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, and
  - 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, and N immobilization in stable SOM fractions

References

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