Soil physical and hydrological properties as affected by long-term addition of various organic amendments

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Introduction

➢Recycled organic wastes, like composts or manures, are used as amendments in agriculture.

➢Physicochemical soil properties are affected by quantity and quality of exogenous organic matter (EOM).

➢Soils with increased organic carbon (OC) content generally display lower bulk densities (BD) / higher porosity and higher water holding capacities (WHC) *(Khaleel et al., 1981)*.

➢The amount of plant available water (PAW) may be influenced *(Foley & Cooperband, 2002)*.

➢Plastic and liquid limit (PL & LL, driven by clay & OC content) indicate water contents where soil consistency changes (*Atterberg, 1911*).

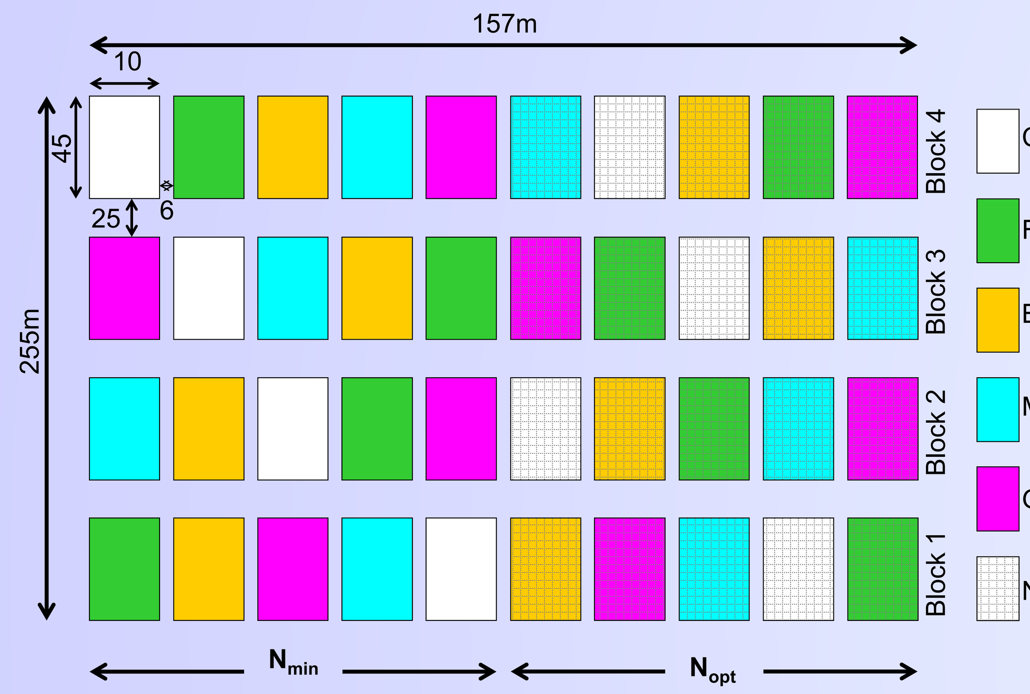


Fig. 1: Layout of Qualiagro; CNT = control, FYM = manure, BIO = biowaste compost, MSW = municipal solid waste compost, GWS = green waste and sewage sludge compost, N_{min} = mineral N at min. rate, N_{opt} = mineral N at opt. rate.

Materials & Methods

Qualiagro site (Fig. 1)

➢Experiment on recycled organic wastes, near Paris, FR since 1998 (INRA - Veolia collaboration).

➢The soil is a loess-derived silt loam (topsoil: 787 g/kg silt, 152 g/kg clay).

➢40 plots with 3 composts, manure and a control at 2 levels of N.

➢Amendments (~4 tC/ha) are applied every other year (Fig. 2).

➢Topsoil OC initially at 10.5 g/kg.

Sampling March 2013

➢3 undisturbed cores (50 cm³) per plot for water retention.

➢Bulk soil for additional soil physical measurements, e.g. plasticity.

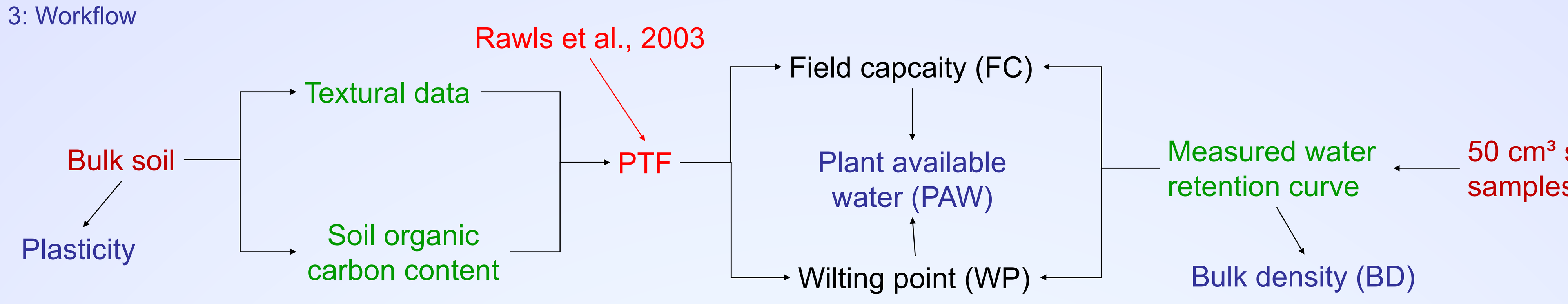
Pedotransfer functions (PTFs)

➢PTFs *(Rawls et al., 2003)* were used to predict water contents at field capacity (FC), wilting point (WP) and plant available water (PAW) .

Workflow Fig. 3

Fig. 2: Application of the organic amendments at the Qualiagro field experiment in fall 2006.

Fig. 3: Workflow



Results & Discussion

Effect of EOM on soil physical properties

➢Appropriate N management (CNT N_{opt}) kept OC near its original level, CNT N_{min} depleted it; EOM addition significantly increased OC.

➢2 EOMs increased total porosity compared to CNT N_{opt} .

➢Control plots display higher values of BD compared to initial conditions in 1998 as well as to organically amended plots.

➢PL and LL increased in amended plots, while no impact of mineral N on soil plasticity was observed.

➢A Plasticity Index (PI) between 5-10 indicates a low plasticity for all soils investigated.

Table 1: Soil physical properties in 6 selected treatments.

Soil	OC 2011	Total porosity	BD 2013	PL 2013	LL 2013	PI (=LL-PL)
	g/kg	cm³/cm³	g/cm³	wt%		%
CNT N_{min}	9.4	0.39	1.42	25.0	32.0	7.1
CNT N_{opt}	10.4^{d}	0.41	1.41	25.3^{b}	31.8^{b}	6.6
MSW N_{opt}	12.8^{c}	0.41	1.30	26.8^{ab}	35.6^{a}	7.3
FYM N_{opt}	14.4^{b}	0.41	1.31	27.9^{a}	35.2^{a}	8.8
BIO N_{opt}	15.2^{a}	0.44	1.30	27.1^{ab}	34.8^{a}	6.7
GWS N_{opt}	15.6^{a}	0.45	1.27	28.2^{a}	34.9^{a}	7.5
1998	*10.5*	/	*1.32*	/	/	/

Superscripted letters indicate statistically significant differences at 5% level (Newman-Keuls test)

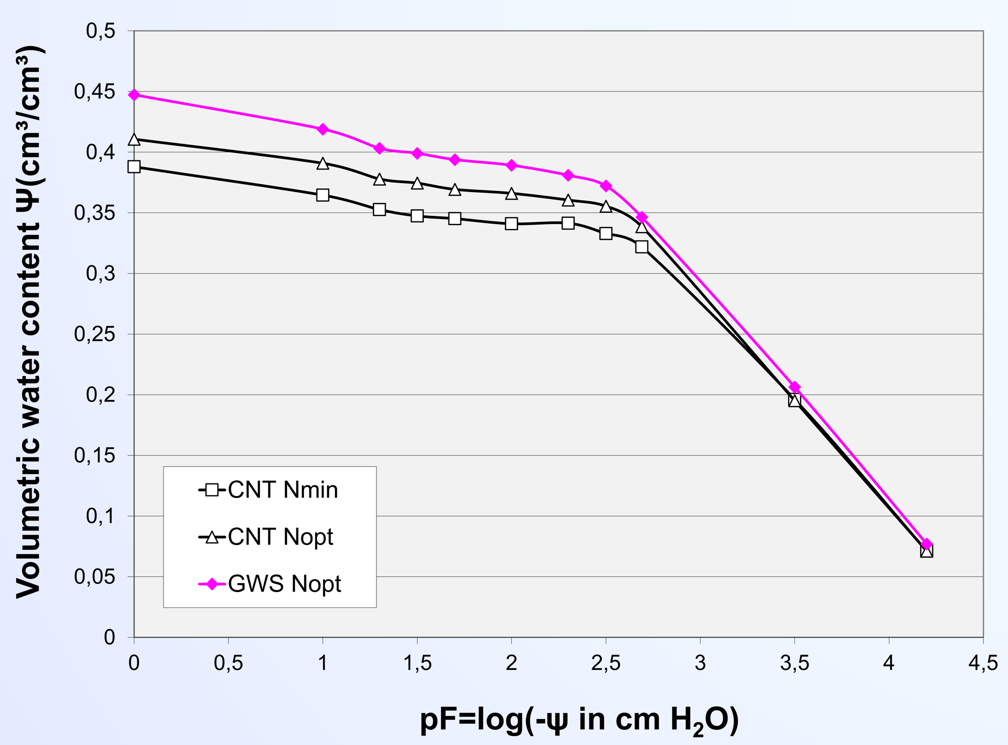


Fig. 4: Water retention curves of 3 selected treatments.

Effect of EOM on soil hydrological properties

➢Soil water retention was affected by the different treatments (Fig. 4).

➢Optimum vs. minimal addition of mineral N increased the volume of large pores; no difference at the dry end (small pores) was observed.

➢Amended soils showed varying responses for water retention:

1. Addition of EOM increased the volume of large pores, especially larger than 300µm (data not shown).
2. Some amendments increased water retention between pF1 and pF3 as compared to CNT N_{opt} (see also Table 2).
3. At the dry end, all amendments increased water retention.

➢CNT N_{min} generally displayed the lowest values measured at each matric potential (exception: MSW N_{opt} was lower at the drier end).

Table 2: Field capacity, wilting and plant available water: modelled and measured (cm³/cm³); ^{p}=predicted *(*PTFs*)*, ^{m}=measured.

Soil	FC^{p}	WP^{p}	PAW^{p}	FCa^{m}	FCb^{m}	WP^{m}	PAW^{m}	PAW^{m}
	pF2.5	pF4.2		pF2	pF2.5	pF4.2	FCa-WP	FCb-WP
CNT N_{min}	0.331	0.107	0.224	0.341±0.00.1	0.333±0.00.1	0.071	0.270	0.262
CNT N_{opt}	0.334	0.108	0.226	0.366±0.00.1	0.355±0.00.1	0.071	0.295	0.284
MSW N_{opt}	0.341	0.110	0.232	0.347±0.00.1	0.333±0.00.1	0.073	0.275	0.260
FYM N_{opt}	0.346	0.111	0.235	0.357±0.00.4	0.342±0.00.4	0.078	0.279	0.264
BIO N_{opt}	0.349	0.112	0.237	0.374±0.00.3	0.354±0.00.3	0.079	0.296	0.275
GWS N_{opt}	0.350	0.112	0.238	0.389±0.00.2	0.372±0.00.2	0.077	0.312	0.295

Effect of EOM on plant available water (PAW)

➢OC-induced aggregation (increases porosity) and increased surface area increase WHC at FC and WP, respectively.

➢Based on texture and OC, FC and WP were predicted with PTFs; resulting PAW increases with OC content (Table 2).

➢Measured values differed from predictions especially at the WP and CNT N_{opt} at FC (pF2.5); amended plots followed the same OC-order.

➢CNT N_{min} generally displayed the lowest values for FC, WP & PAW.

➢CNT N_{opt} showed no change at WP (compared to CNT N_{min}) but was higher than some amended plots at FC.

➢GWS N_{opt} was most effective in increasing water retention and PAW, MSW N_{opt} was least effective.

Conclusions

➢3 composts and a manure **increased OC** at different rates and **reduced BD**; the plastic limits shifted in amended plots.

➢Addition of N or EOM+N **increased water retention** capacity of soils.

➢Increased total porosity and large-pore volume indicate **improved aeration** conditions in amended soils.

➢OC derived from EOM induced **aggregation** (creating inter- and intra-aggregate pores) and increased **surface area**: both factors affect water retention.

➢Compared with CNT N_{min} EOM addition increased water retention at **FC & WP**, CNT N_{opt} **only at FC**, not at WP.

➢**GSW and BIO** decompose slowly, their effect on OC and related properties is long-lasting / stable; **MSW** contained more labile components, which may explain its smaller impact on OC and especially water retention.

➢The effect of EOM on PAW appears to be linked to the **quality of EOM**.

Perspectives

➢Quantification of the 'non-nitrogen' yield benefit of the different composts.

➢Evaluate the quality of composts / manure used in regard to soil physical properties and plant growth and yield (Fig. 5).

Fig. 5: Winter wheat growing on the experimental fields in Qualiagro.

Acknowledgements

We thank Lydia Paetsch (TUM) and Dr. Remigio Paradelo (INRA) for providing additional data. This work was granted by ADEME within the Pro-Extern project.

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