Effects of long-term compost application on carbon content and soil physical properties

Marie Eden & Sabine Houot

INRA-AgroParisTech, UMR-EGC Sol, 78850 Thiverval-Grignon, France (meden@grignon.inra.fr)

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) applied as amendments.
- Soils with increased organic carbon (OC) content generally display higher water holding capacities (WHC) *(Khaleel et al., 1981)*.
- The amount of plant available water (PAW = field capacity - wilting point) influences irrigation needs *(Foley & Cooperband, 2002)*.
- Soils with increased OC content generally display lower bulk densities (BD); denser soils can negatively affect rooting depth *(Zisa et al., 1980)*.

Fig. 1: Irrigation system (source: www.cyberartsweb.org)

Materials & Methods

Qualiagro site (Fig. 2)

- 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.
- Topsoil OC ranges from 9.35 to 15.58 g/kg (2011), initially 10.5 g/kg.

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) .

BUDGET *(Raes et al., 2006)*

- The soil water balance model was used to evaluate irrigation needs.
- Local climatic data from 2007 & 2008 was used for modelling.

Workflow

- Workflow depicted in Fig. 3.

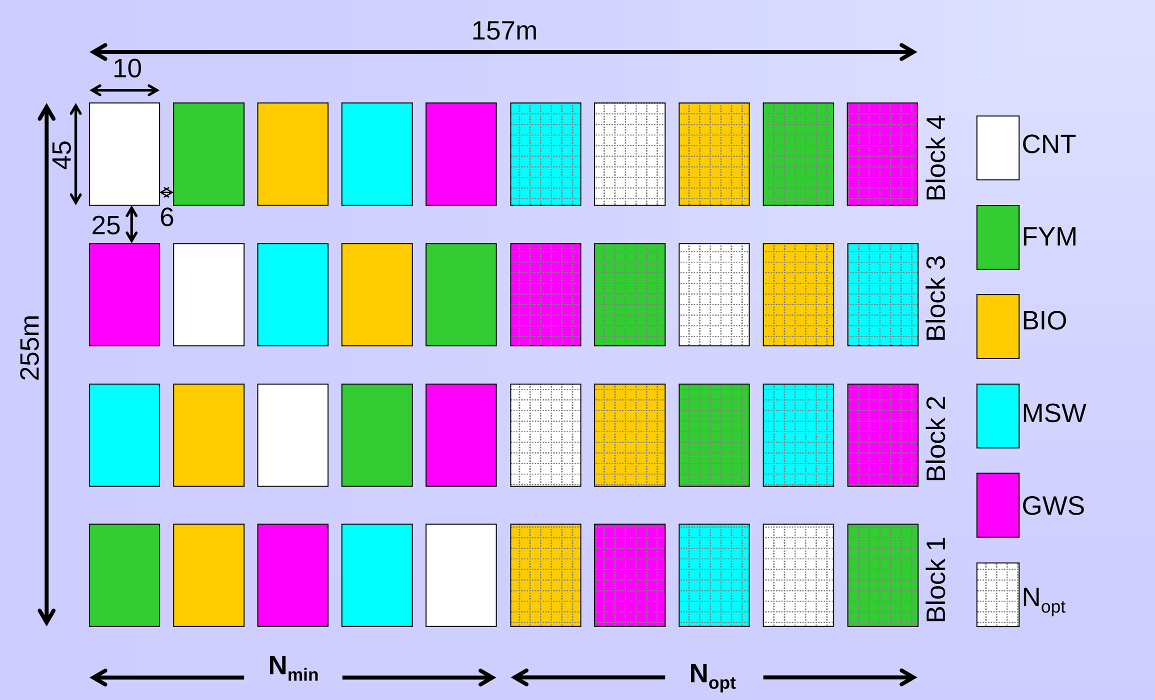
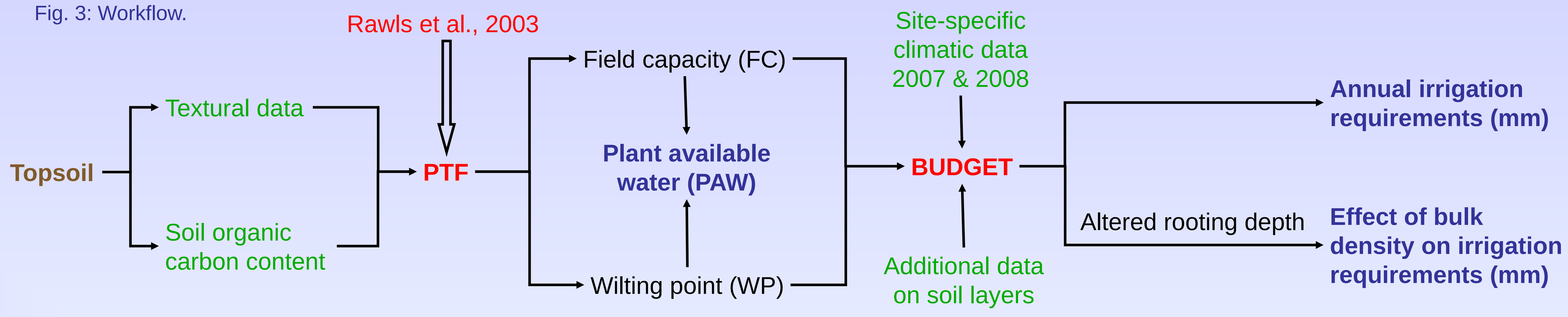


Fig. 2: Layout of Qualiagro; CNT = control, FYM = manure, BIO = biowaste compost, MSW = municipal solid waste compost, GWS = green waste and sewage sludge compost, N_{min} = mineral N at min. rate, N_{opt} = mineral N at opt. rate.

Fig. 3: Workflow.



Results & Discussion

Effect of EOM on irrigation

- Fig. 4 shows the simulated distribution of daily irrigation needs for CNT N_{min} in 2007.
- Appropriate N management (CNT N_{opt}) kept OC near its original level, CNT N_{min} depleted it; EOM application increased OC for all treatments (Table 1).

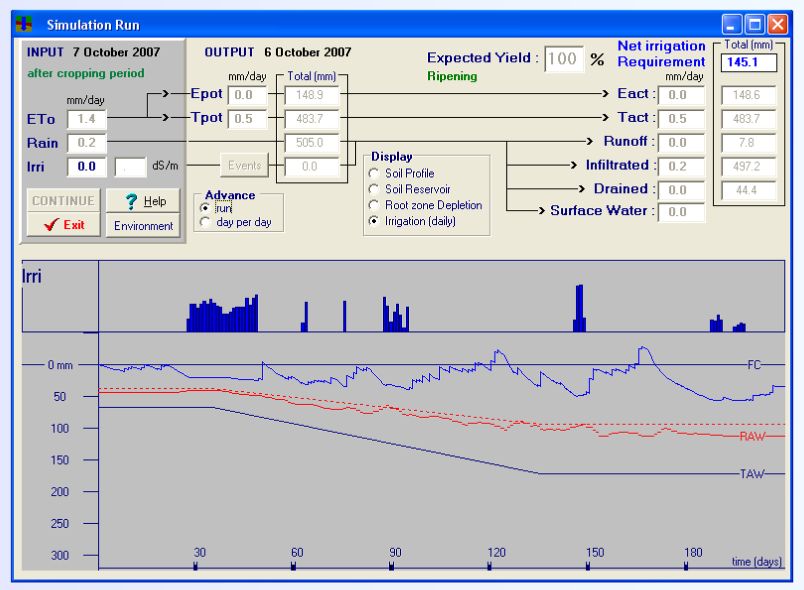


Fig. 4: Output screen of daily irrigation needs for CNT N_{min} in 2007 with BUDGET.

Table 1: Irrigation needs and topsoil OC and water contents.

Soil	OC	FC[p]	WP[p]	PAW[c]	Irrigation needs (mm)	
	g/kg	-------------Vol%		--------------	2007[m]	2008[m]
CNT N_{min}	9.4*	33.1	10.7	22.4	145.1[f]	397.4
CNT N_{opt}	10.4*	33.4	10.8	22.6	144.1	396.7
MSW N_{opt}	12.8*	34.1	11.0	23.2	142.2	395.7
FYM N_{opt}	14.4*	34.6	11.1	23.5	141.3	395.0
BIO N_{opt}	15.2*	34.9	11.2	23.7	140.7	394.6
GWS N_{opt}	15.6*	35.0	11.2	23.8	140.4	394.4
C_{high}	20.0[h]	36.3	11.6	24.7	132.2	393.0

*=measured, [h]=hypothetical, [p]=predicted *(PTFs)*, [c]=calculated, [m]=modelled, [f]=shown in Fig. 3

- Based on texture and OC, FC and WP were predicted *(PTFs: Rawls et al., 2003)*; resulting PAW increases with OC content (Table 1).
- OC-induced aggregation (thereby increased porosity) and increased surface area increase WHC at FC and WP, respectively.
- A larger increase at FC than at WP resulted in a net gain in PAW (Table 1).
- Simulating irrigation needs with BUDGET showed that increased PAW slightly decreased irrigation needs.

Effect of OC-affected topsoil-BD on irrigation

- BD may impact rooting depth; limiting values are texture-dependent *(Daddow & Warrington, 1983)*.
- Root penetration in silt loam may already be restricted at a BD of 1.4 g/cm³ *(Zisa et al., 1980)*.
- Root growth determines access to water and future yield.

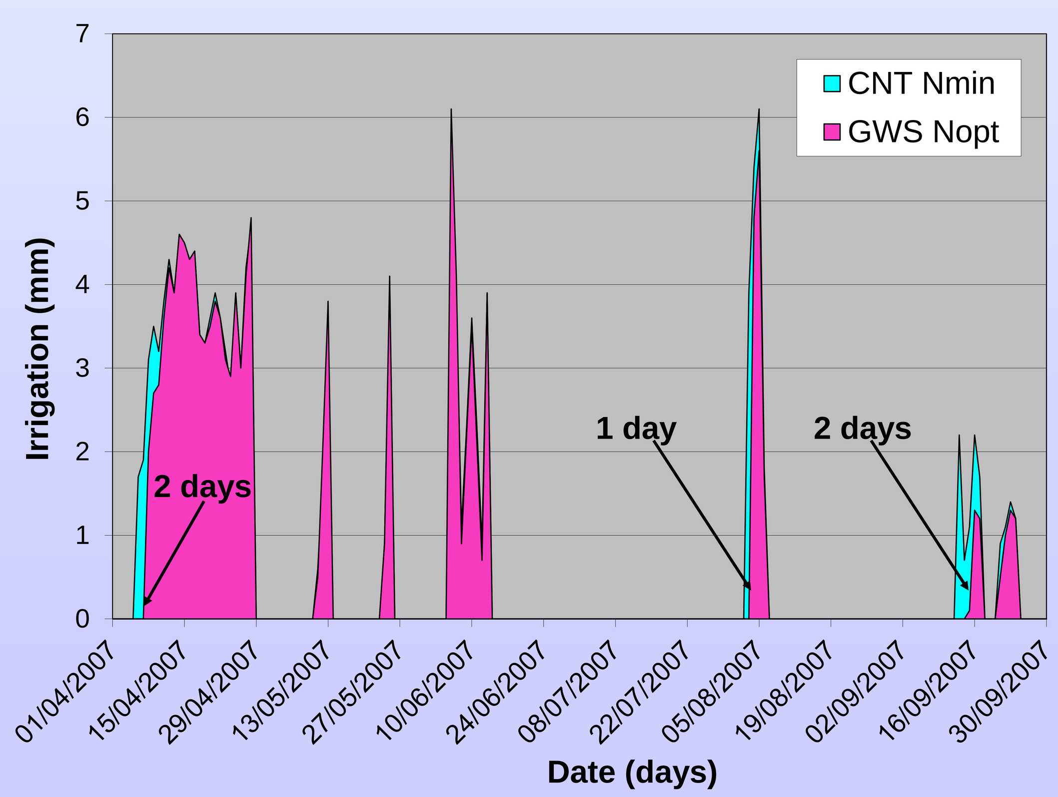


Fig. 5: Distribution of daily irrigation needs for CNT N_{min} & GWS N_{opt} in 2007 with BUDGET; CNT N_{min} requires irrigation on 5 days more (indicated).

Table 2: Irrigation needs, topsoil density and rooting depth.

Soil	BD (2009) topsoil g/cm³	Rooting depth (m)		Irrigation needs (mm)	
		Initial stage (min)	Mid-season stage (max)*	2007[m]	2008[m]
CNT N_{min}	1.42	0.25	1[d]	146.1	398.2
		0.3[d]	0.95	146.3	397.8
		0.25	0.95	146.4[f]	400.1
GWS N_{opt}	1.31	0.35	1[d]	139.1	394.4
		0.3[d]	1.05	130.6	389.7
		0.35	1.05	130.1[f]	388.5

*=as affected by topsoil density, [d]=default values, [m]=modelled, [f]=shown in Fig. 4

- Table 2 shows irrigation needs for two soils at altered rooting depths; decreased for CNT N_{min} and increased for GWS N_{opt}.
- CNT N_{min}: reduced rooting depths in both stages has strongest effect (both years).
- GWS N_{opt} : increased rooting depth in mid-season has a larger impact on irrigation needs than during initial stage.
- BUDGET simulates the need of irrigation on fewer days for GWS N_{opt} than CNT N_{min} in 2007 (Fig. 5). On 3 occasions water reserves would last longer (1-2 days).
- An irrigation system (Fig. 1) can be used less or for more areas.

Conclusions

- 3 composts and a manure **increased OC** at different rates; a control with sufficient N kept OC near its original level from 1998.
- GSW and BIO decompose slowly, their effect on OC is long-lasting / stable; MSW contained more labile components, its effect was sooner detectable but smaller.
- According to predictions (PTFs), all treatments **increased PAW** (OC-dependent) and hence **reduced** BUDGET-simulated **irrigation needs**.
- Irrigation needs were larger in 2008 (597 mm precipitation: average year) than in 2007 (777 mm precipitation: wet year).
- An OC-depleted, denser soil may restrict root growth and require more irrigation.
- On average **~4 mm of water can be saved** comparing CNT N_{min} to GWS N_{opt} (Table 1), this corresponds to 4 l/m² (Fig. 6) or 40.000 l/ha.
- Further increasing OC (C_{high}) could decrease irrigation needs by ~13 mm; Foley & Cooperband (2002) observed decreases of 7-34 mm for compost-amended soils.

Perspectives

- Actual measurements of the water retention curve of the respective treatments will be made to determine OC-induced changes in WHC and PAW.
- Quantification of the 'non-nitrogen' yield benefit of the different composts.
- Possible determination of leaf water potential as a potentially better indicator of the effect of compost on soil and plant *(Mamo et al., 2000)*.

Fig. 6: Average of maximum amount of water saved (comparing CNT N_{min} to GWS N_{opt}) in both years of simulation: ~4mm ≙ **4 l/m²** ≙ 40.000 l/ha

References

Daddow R.L., Warrington G.E. 1983. Growth-limiting soil bulk densities as influenced by soil texture, USDA Forest Service, Fort Collins, CO. pp. 17.

Foley B.J., Cooperband L.R. 2002. Paper mill residuals and compost effects on soil carbon and physical properties. J. Environ. Qual. 31:2086-2095.

Khaleel R., Reddy K.R., Overcash M.R. 1981. Changes in soil physical-properties due to organic waste applications - review. J. Environ. Qual. 10:133-141.

Mamo H., Moncrief J.F., Rosen C.J., Halbach T.R. 2000. The effect of municipal solid waste compost application on soil water and water stress in irrigated corn. Comp. Sci. Util. 8:236-246.

Raes D., Geerts S., Kipkorir E., Wellens J., Sahli A. 2006. Simulation of yield decline as a result of water stress with a robust soil water balance model. Agr. Water Manage. 81:335-357.

Rawls W.J., Pachepsky Y.A., Ritchie J.C., Sobecki T.M., Bloodworth H. 2003. Effect of soil organic carbon on soil water retention. Geoderma 116:61-76.

Zisa R.P., Halverson H.G., Stout B.B. 1980. Establishment and early growth of conifers on compact soils in urban areas. USDA Forest Service Research Paper NE-451. pp. 8.

Acknowledgements

This work was granted by ADEME within the Pro-Extern project.