



# Soil structure -soil microorganisms interactions: decomposing organic matter in a structured world

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## Soil structure - soil microorganisms interactions: *decomposing organic matter in a structured world*

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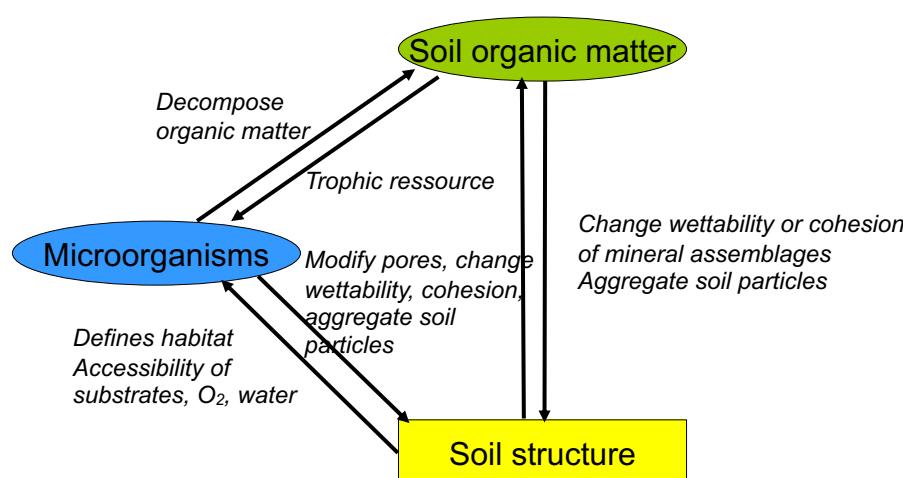
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Soil systems course- C.Chenu- 2021-12-01

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## Interactions between microorganisms, soil structure and soil organic matter



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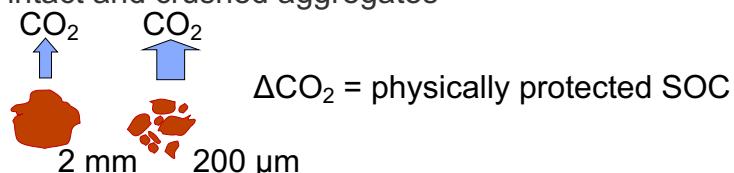
Soil systems course- C.Chenu- 2021-12-01

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## 1- Does structure matter for biodegradation of organic matter ?

### Soil structure does matter: crushing experiments

- Incubating intact and crushed aggregates



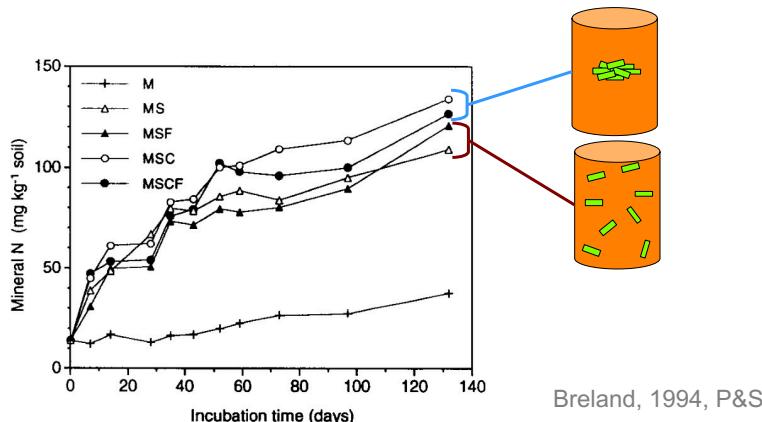
Treatment	Scale	C mineralization crushed/intact		
		nb	mean	range
Crushed < 1 mm	Macroaggregates	6	1.3	0.8-2.3
Crushed < 0.25 mm	Microaggregates	12	1.17	1.04 -1.3
Crushed < 0.15 mm	Microaggregates	4	1.24	1.14 -1.34
Ground < 0.15 mm	Microaggregates	4	7.1	4.3-10.8

Litterature review (Balesdent et al. 2000)

→Aggregates protect SOC and protection is more important at finer scales

## Soil structure does matter: manipulative experiments

- N mineralization from soil after plant residues addition:

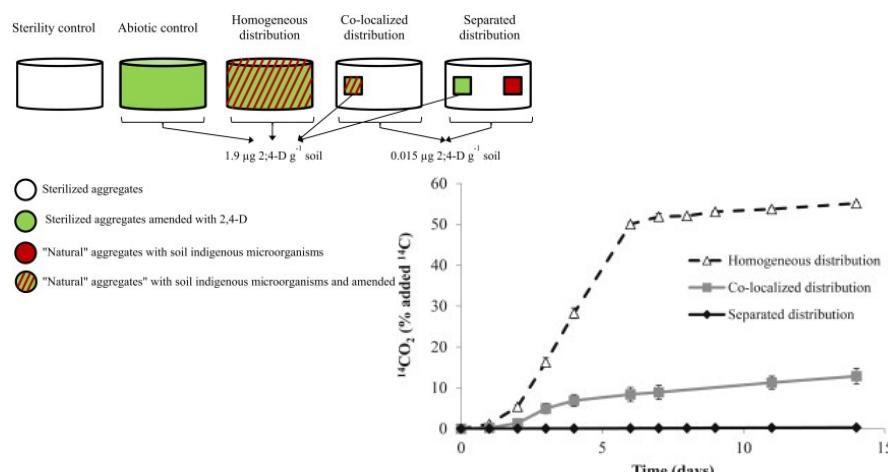


→ less N mineralization of homogenously distributed residues: protection by the matrix ?

5

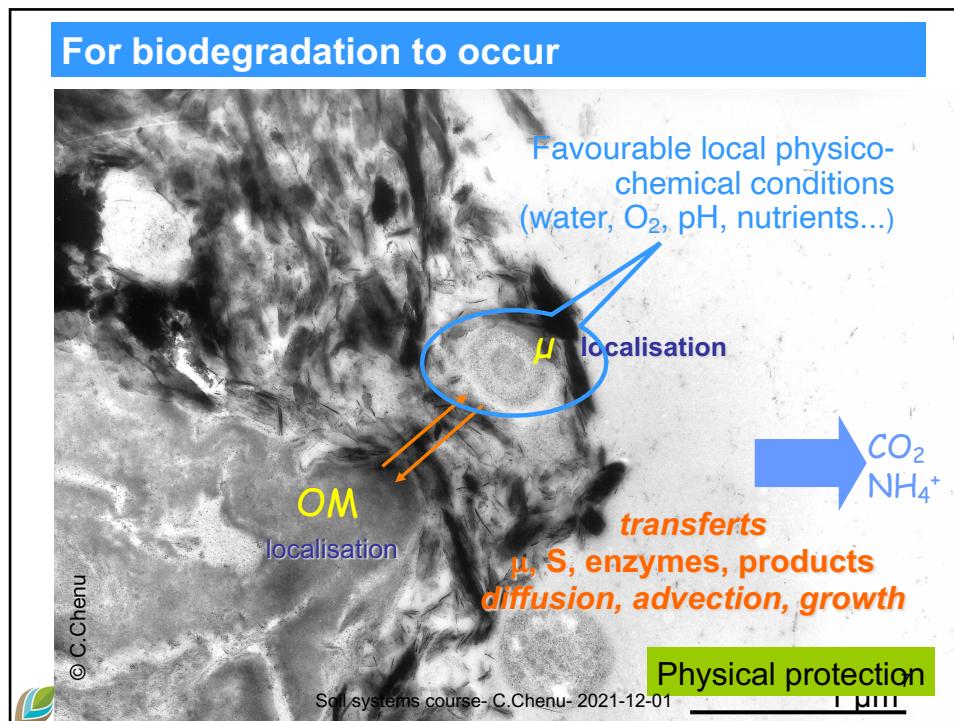
## Soil structure does matter: manipulative experiments

- Manipulating the spatial distribution of  $\mu$  and substrates

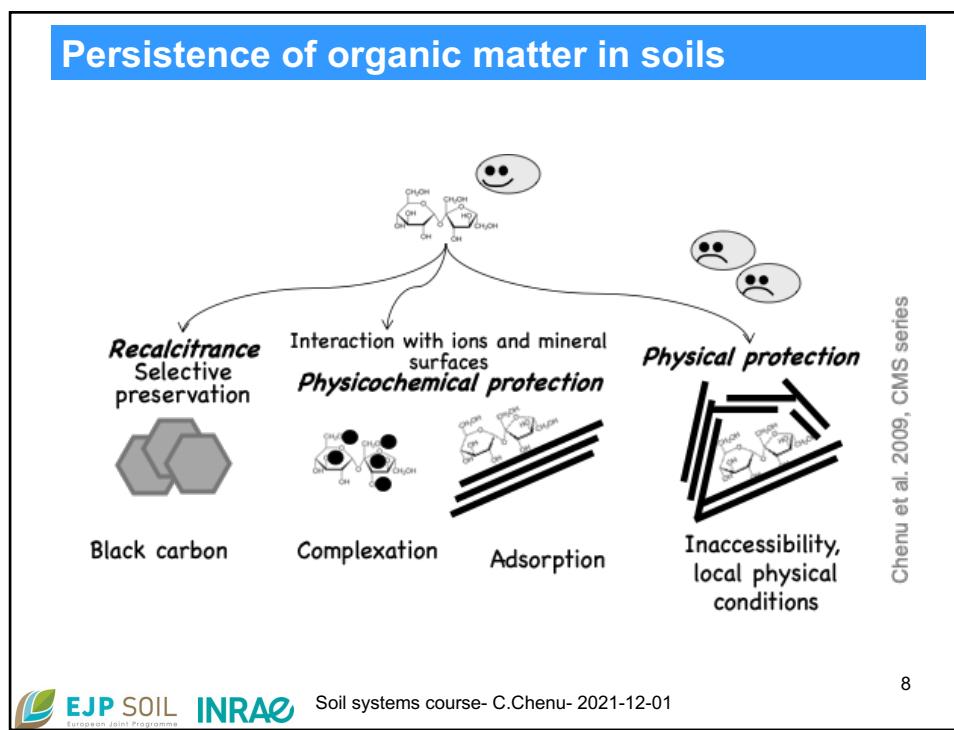


→ accessibility controls mineralisation

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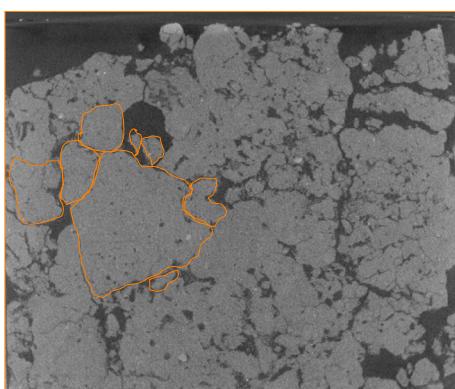
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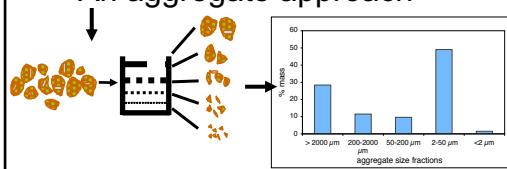
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## 2- Spatial heterogeneity of microbally - mediated biodegradation

## How is soil structure viewed ?



An aggregate approach



## Separating SOM in different locations & measuring their residence time

- Aggregate of ≠ sizes

Ecosystem	macroaggregates		microaggregates	
	Size (µm)	MRT (y)	MRT (y)	Size (µm)
Tropical pasture	> 200	60	75	< 200
Temperate pasture	212-9500	140	412	53-212
Soybean	250-2000	1.3	7	100-250
Maize	>250	14	61	50-250
Maize	>250	42	691	50-250
Wheat-fallow, NT	250-2000	27	137	53-250
Wheat-fallow, CT	250-2000	8	79	53-250

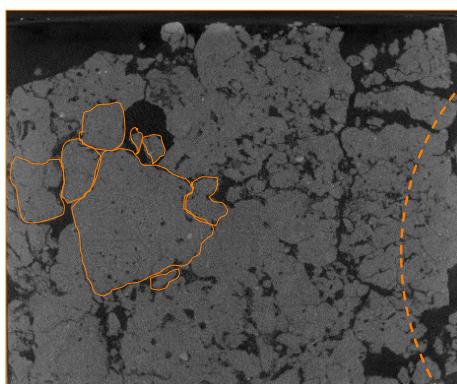
Litterature review (Six & Jastrow, 2002)

- Particulate organic matter free vs occluded
  - Higher residence time inside aggregates (Golchin et al. 1995, Besnard et al. 1996, Six et al. 1998, ect...)

→ Turnover of SOC is slower within aggregates and in small ones

## Protection of OM by soil aggregates: problems

©W Otten



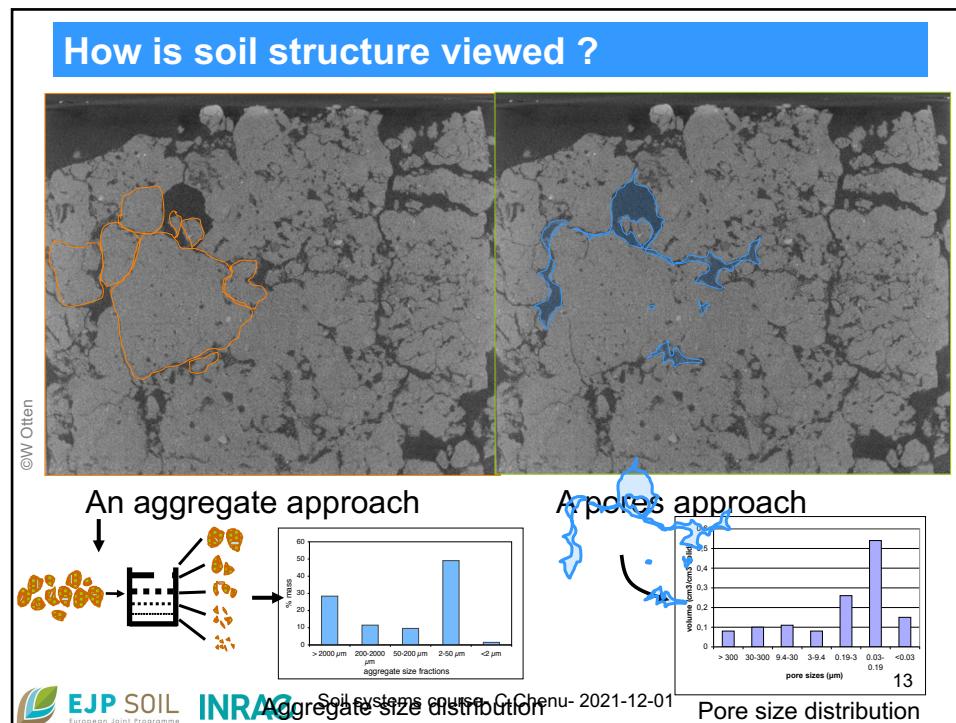
Pb 1: scales !

20 µm

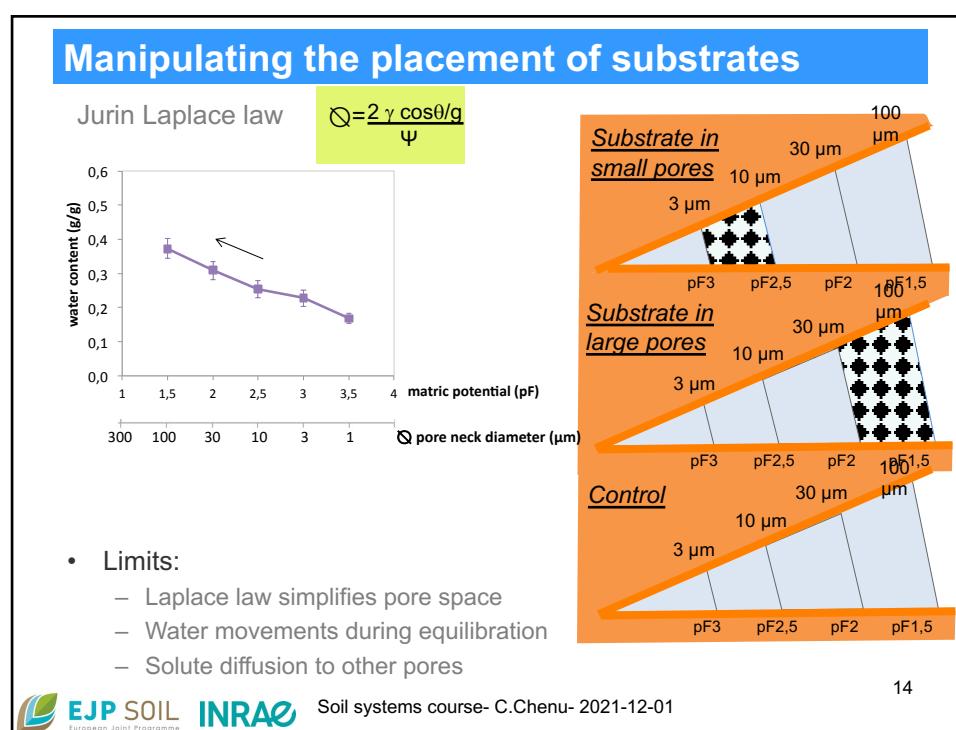
50 µm

Pb 2: turnover rate of aggregates: days ! (Plante et al.

2002; de Gryze 2004) or a year (Virto et al. 2010)



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## # microbial activities in ≠ pores size classes?

### Experiment 1 Native soil microbial community

- $^{13}\text{C}$  labelled fructose solution or water added at different matric potentials to soil cores

$\Psi$ (kPa)	$\Theta$ pores targeted
-1000 → -100	0.3 → 3 $\mu\text{m}$
-315 → -3,15	1 → 100 $\mu\text{m}$
-31,5 → -1	10 → 300 $\mu\text{m}$

$$\Theta = \frac{2 \gamma \cos \theta / g}{\Psi}$$

Postulate: consumption of  $^{13}\text{C}$  labelled substrate primarily in pore size classes targeted



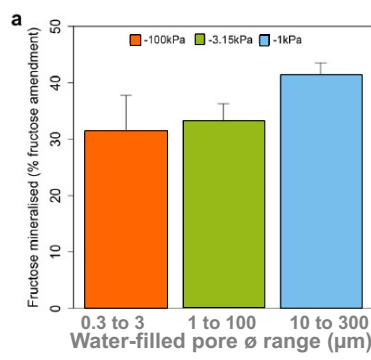
- Incubated for two weeks : total and  $^{13}\text{C}$ -labelled  $\text{CO}_2$
- At end of incubation: total PLFA profiles and  $^{13}\text{C}$ -enriched PLFA profiles

Ruamps et al. (2011) *Soil Biol & Biochem*

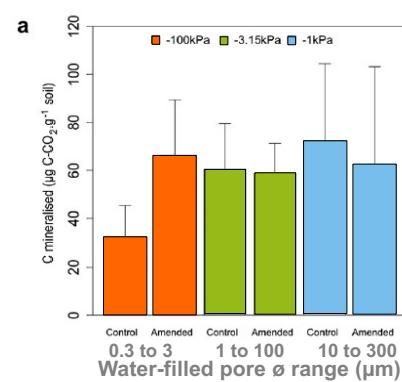
## # microbial activities in ≠ pore size classes ?

### Experiment 1 Native soil microbial community

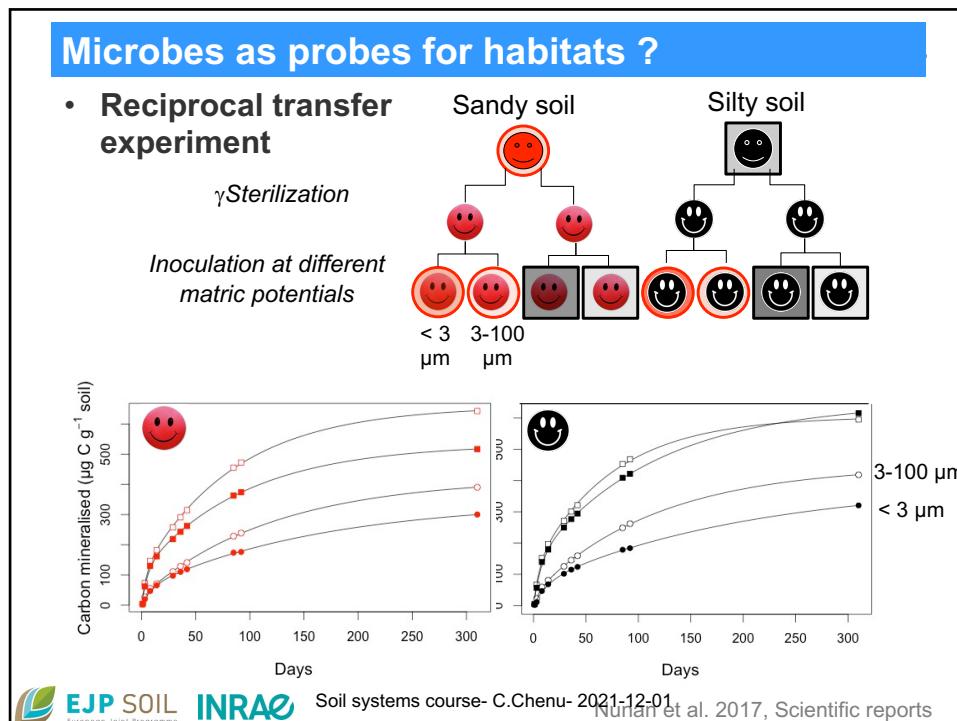
#### $^{13}\text{C}$ -fructose mineralisation



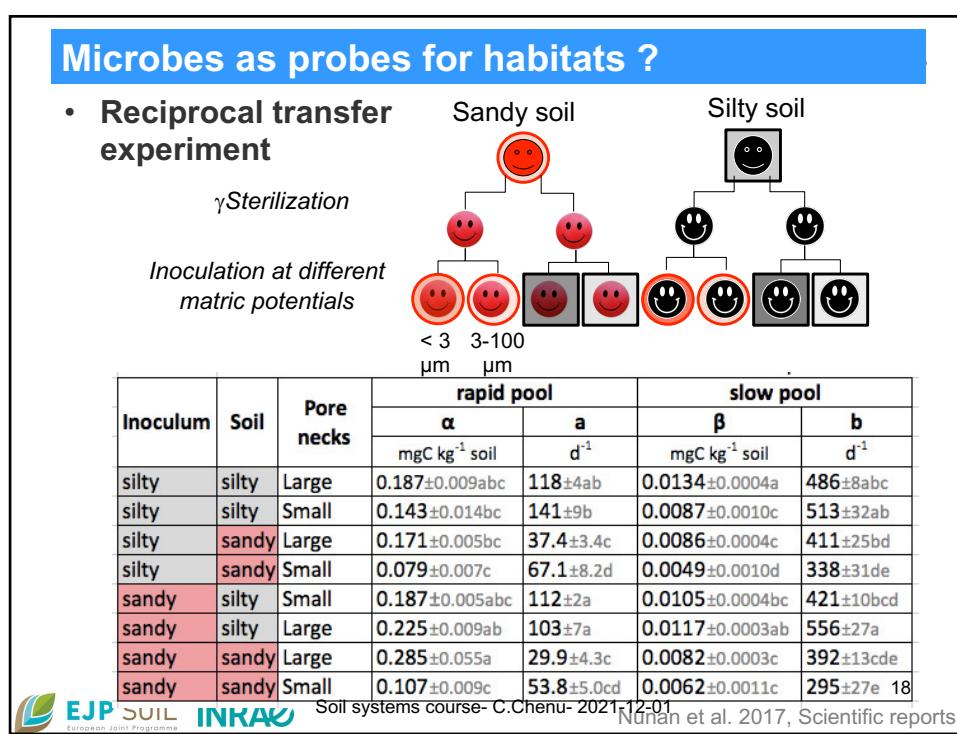
#### Native SOM C mineralisation



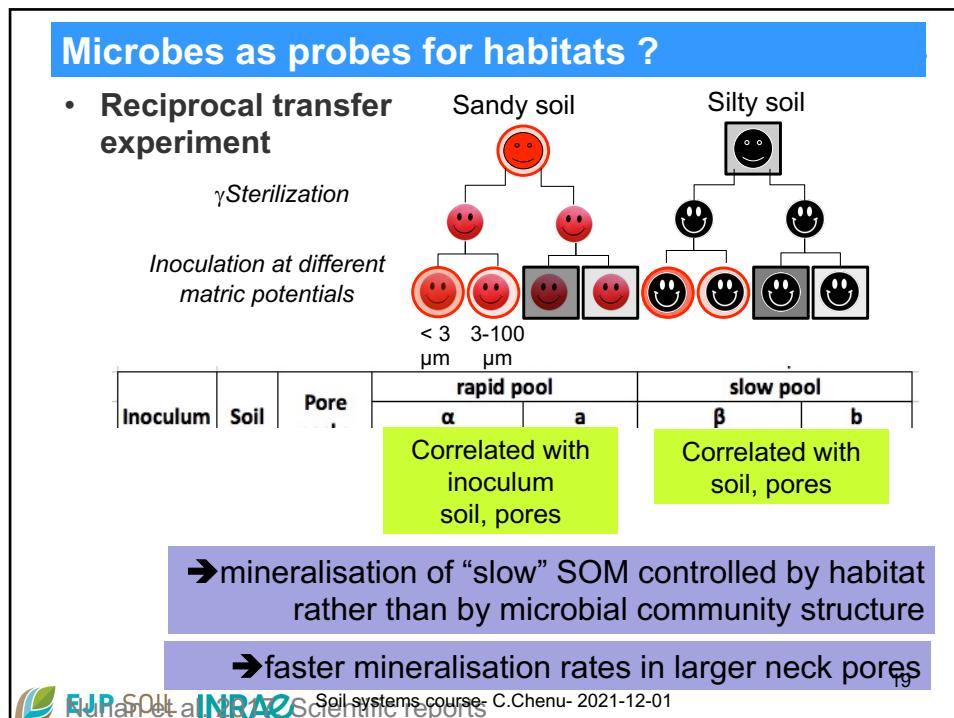
Differences in activity: due to  $\mu$  or local conditions?



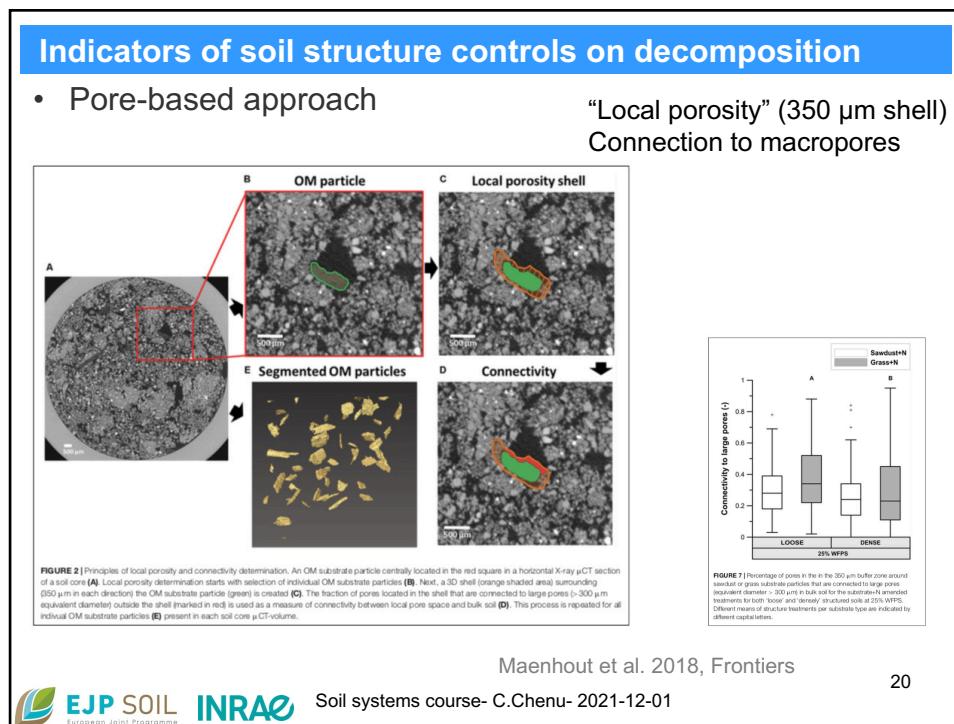
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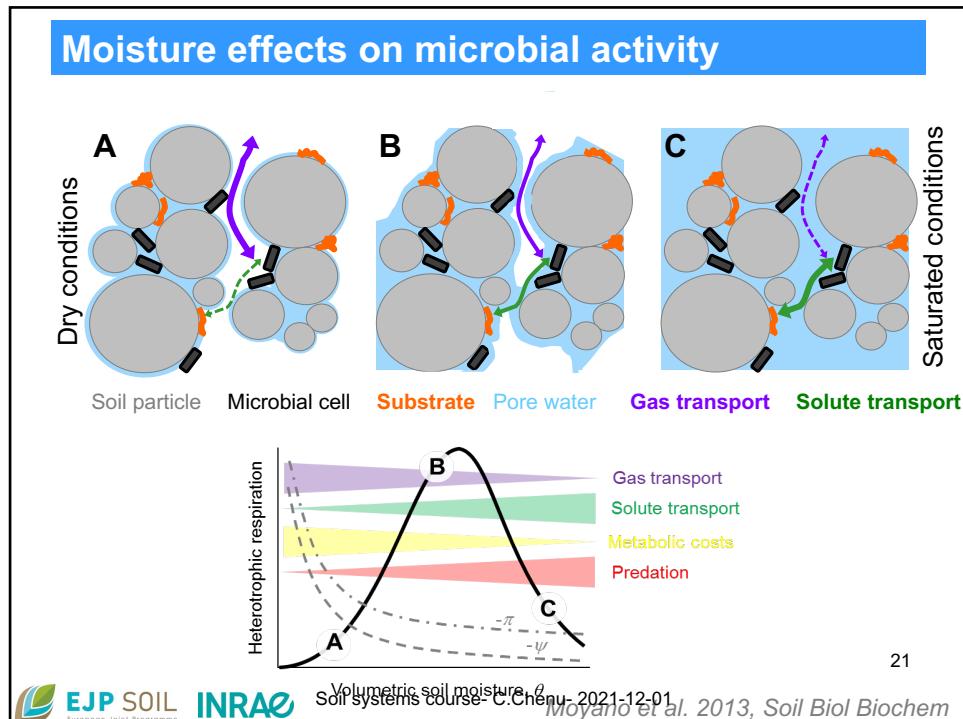
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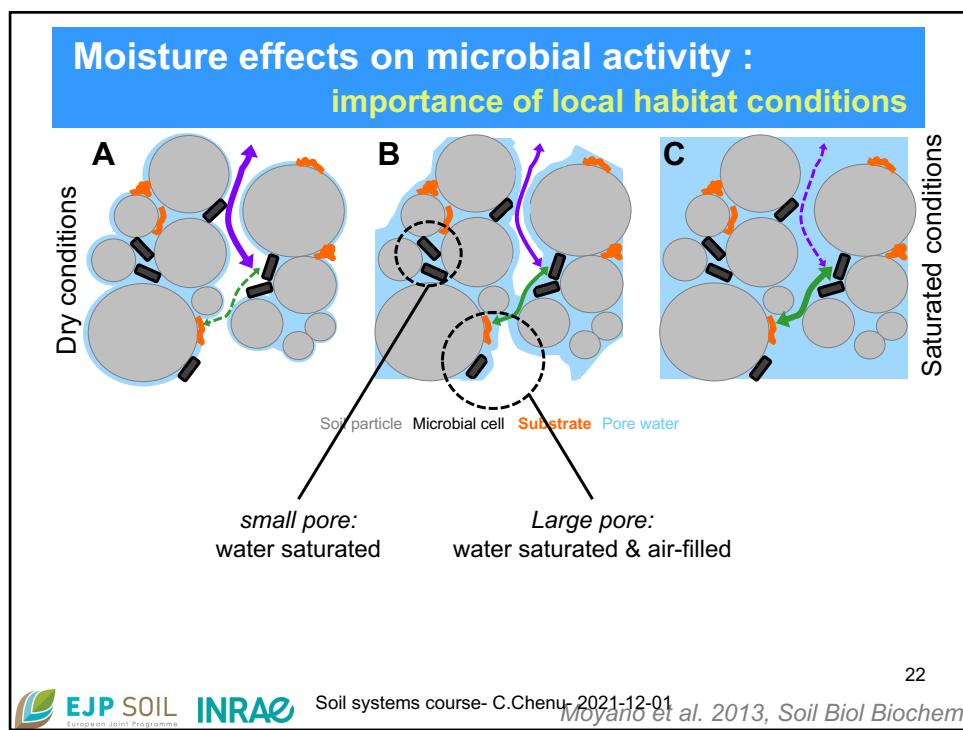
19



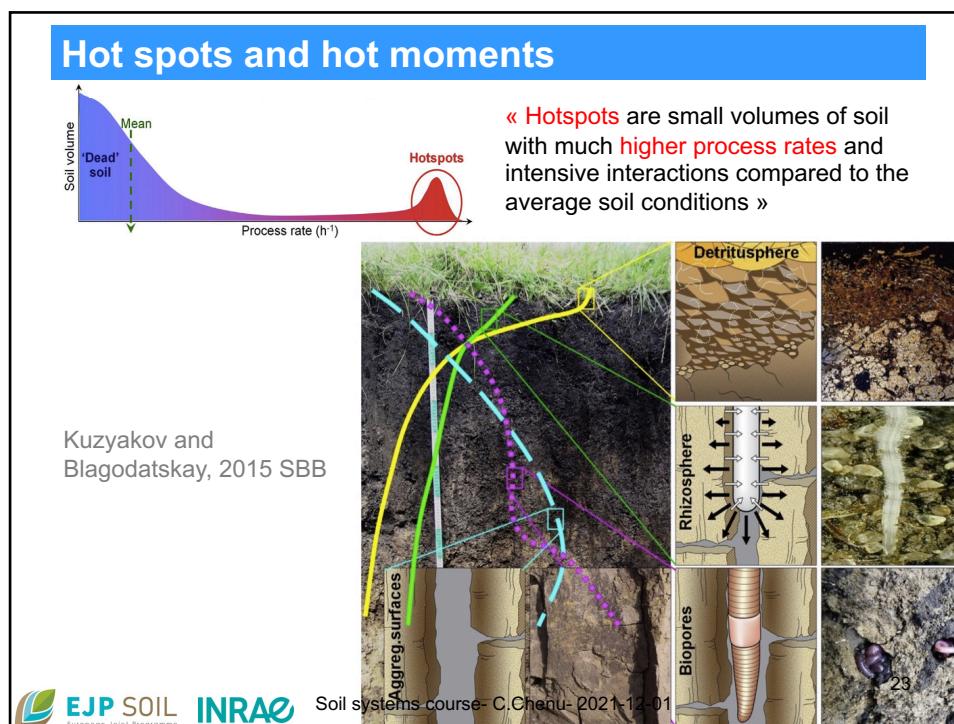
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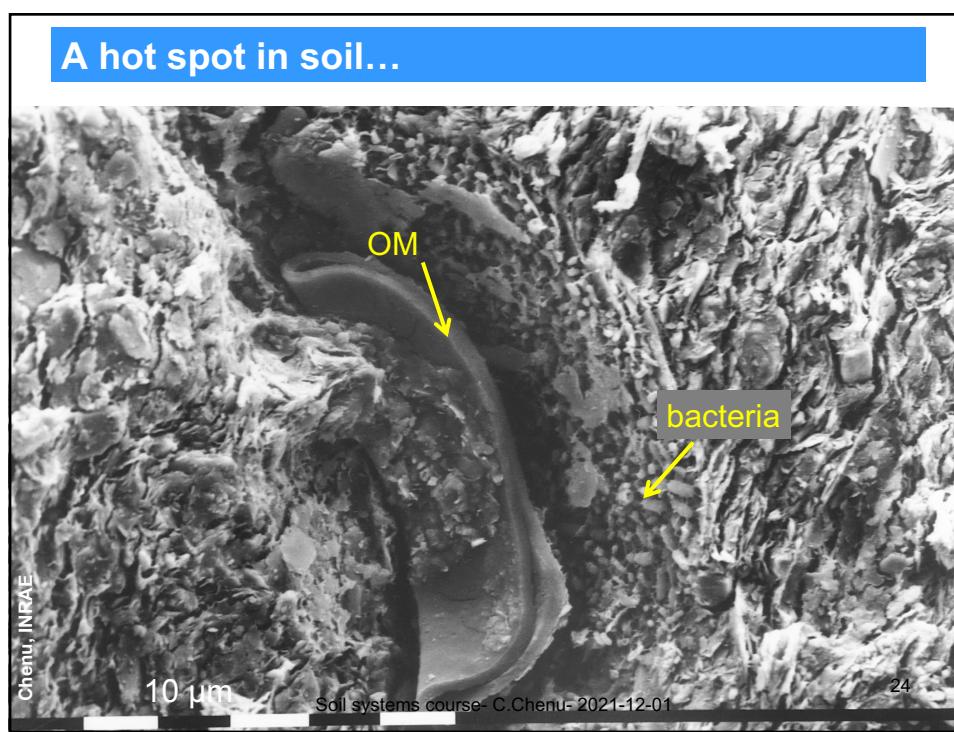
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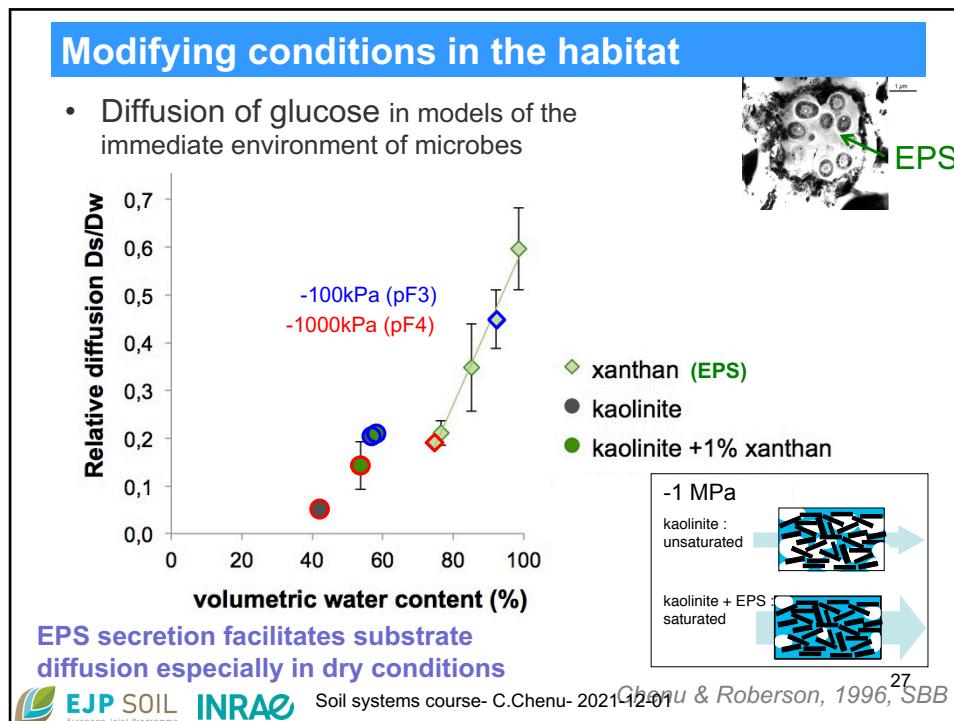
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### 3- Feedbacks: effects of microorganisms on soil structure (*related to OM decomposition*)

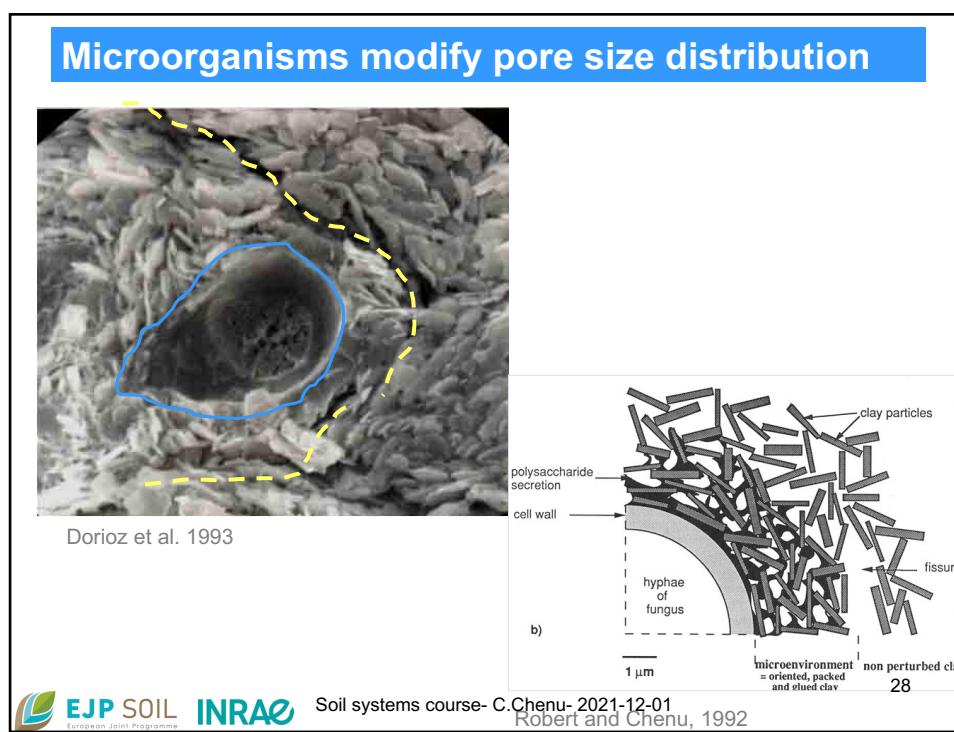
#### Bacterial microaggregate



Transmission electron microscopy  
Staining of polysaccharides with silver proteinate

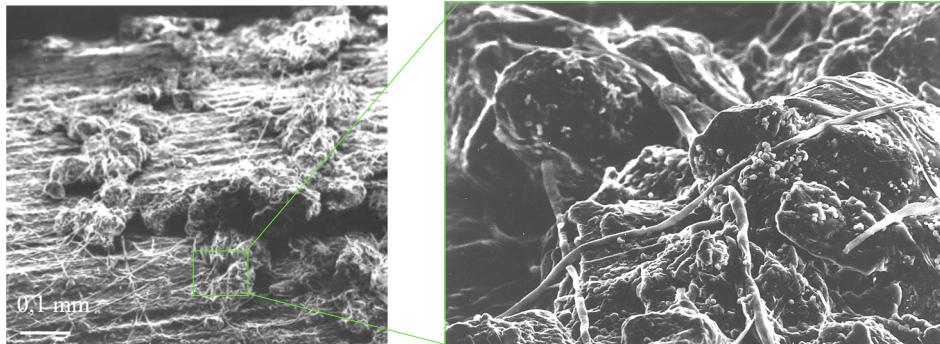


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## Soil aggregation by microbial decomposers: physical entanglement

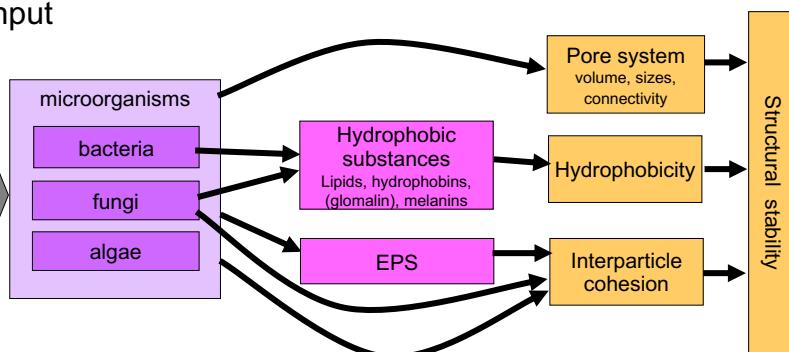


Angers & Chenu, 1998

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## Microbial controls on aggregate stability

OM input



Chenu & Cosentino, CABI 2011

## References cited

- Angers, D.A., Chenu, C., 1997. Dynamics of soil aggregation and C sequestration. In: R. Lal, J. Kimble, R.F. Follet, B.A. Stewart (Eds.), *Soil Processes and the Carbon Cycle*. CRC Press, Boca Raton, pp. pp 199-206.
- Balesdent, J., Chenu, C., Balabane, M., 2000. Relationship of soil organic matter dynamics to physical protection and tillage. *Soil & Tillage Research* 53, 215-230.
- Breland, T.A., 1994. Enhanced mineralization and denitrification as a result of heterogeneous distribution of clover residues in soil. *Plant and Soil* 166, 1-12.
- Chenu, C., Virto, I., Plante, A.F., Elsass, F., 2009. Clay-size organo-mineral complexes in temperate soils: relative contributions of sorptive and physical protection. In: D.A. Laird, J. Cervini-Silva (Eds.), *Carbon Stabilization by Clays*. CMS workshop lectures. The Clay Minerals Society, Chantilly, VA, pp. 120-135.
- Chenu, C., Cosentino, D., 2011. Microbial regulation of soil structural dynamics. In: K. Ritz, I.M. Young (Eds.), *Architecture and biology of soils : life in inner space*. CABI, pp. 37-70.
- Chenu, C., Roberson, E.B., 1996. Diffusion of glucose in microbial extracellular polysaccharide as affected by water potential. *Soil Biology & Biochemistry* 28, 877-884.
- De Gryze, S., Six, J., Merckx, R., 2006. Quantifying water-stable soil aggregate turnover and its implication for soil organic matter dynamics in a model study. *European Journal of Soil Science* 57(5) %R doi:10.1111/j.1365-2389.2006.00760.x, 693-707.
- Doroz, J.M., Robert, M., Chenu, C., 1993. The role of roots, fungi and bacteria on clay particle organization. An experimental approach. *Geoderma* 56, 179-194.
- Golchin, A., 1994. Soil Structure and Carbon Cycling. *Australian Journal of Soil Research* 32, 1043-1068.
- Kuzyakov, Y., Blagodatskaya, E., 2015. Microbial hotspots and hot moments in soil: Concept & review. *Soil Biology and Biochemistry* 83, 184-199.
- Maenhout, P., Van den Bulcke, J., Van Hoorebeke, L., Cnudde, V., De Neve, S., Sleutel, S., 2018. Nitrogen Limitations on Microbial Degradation of Plant Substrates Are Controlled by Soil Structure and Moisture Content. *Frontiers in Microbiology* 9.
- Moyano, F.E., Manzoni, S., Chenu, C., 2013. Responses of soil heterotrophic respiration to moisture availability: An exploration of processes and models. *Soil Biology & Biochemistry* 59, 72-85.
- Nunan, N., Leloup, J., Ruamps, L.S., Pouteau, V., Chenu, C., 2017. Effects of habitat constraints on soil microbial community function. *Scientific Reports* 7.
- Pinheiro, M., Garnier, P., Beguet, J., Martin Laurent, F., Vieublé-Gonod, L., 2015. The millimetre-scale distribution of 2,4-D and its degraders drives the fate of 2,4-D at the soil core scale. *Soil Biology & Biochemistry* 88, 90-100.
- Plante, A.F., McGill, W.B., 2002. Soil aggregate dynamics and the retention of organic matter in laboratory-incubated soil with differing simulated tillage frequencies. *Soil & Tillage Research* 66(1), 79-92.
- Ruamps, L.S., Nunan, N., Chenu, C., 2011. Microbial biogeography at the soil pore scale. *Soil Biology & Biochemistry* 43, 280-286.
- Six, J., Elliott, E.T., Paustian, K., Doran, J.W., 1998. Aggregation and soil organic matter accumulation in cultivated and native grassland soils. *Soil Science Society of America Journal* 62(5), 1367-1377.
- Six, J., Jastrow, J., 2002. Organic matter turnover. *Encyclopedia of Soil Science*. Marcel Dekker Inc., New York, pp. 936-942.
- Virto, I., Moni, C., Swanston, C., Chenu, C., 2010. Turnover of intra- and extra-aggregate organic matter at the silt-size scale. *Geoderma* 156(1/2), 1-10.