Permaculture practices effect on soil fertility and organic matter distribution in aggregate-size classes

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This presentation participates in OSPP
EGU Outstanding Student Poster & PICO Contest

1 INTRODUCTION

The increasing awareness about the negative impacts of modern agriculture (Stoate et al. 2009) has led to the question of a transition towards a resilient and sustainable agriculture model (Ferguson & Lovell 2014). In this regard, micro- or mini-farms inspired from permaculture model (Mollison & Holmgren 1990) and biointensive micro-gardening could potentially play a key role in this transition (Morel et al. 2017). However, these systems have been largely overlooked by soil scientists and generally isolated from scientific research (Ferguson & Lovell 2014).

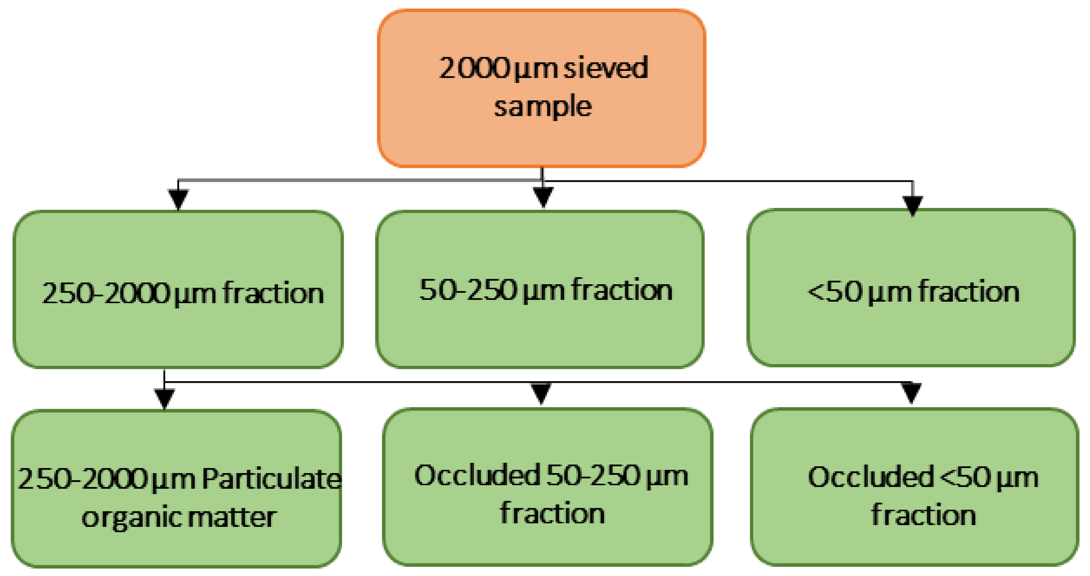
Such practices can be very specific from one system to another but are always characterized by the use of organic fertilizers. Soil organic matter (SOM) plays a fundamental role in soil functioning by maintaining fertility through nutrients recycling and being one of the major compounds of soil aggregates, essential to maintain soil resilience to physical stresses and to enhance carbon storage through physical protection (Six et al. 2002). Henceforth, it is crucial to test the extent to which permaculture practices, **characterized by (1) intensive cultivation (2) the non-use of mineral fertilizers and pesticides and (3) very large and localized organic inputs**, can sustain nutrient release and retention through decomposition processes in soils while increasing OC stocks, to partly compensate human emissions (Dignac et al. 2017).
In this work, we aim to study the effect of permaculture practices characterized by very large and localized organic inputs on soil fertility parameters and SOM allocation in aggregate-size classes.

2 MATERIALS AND METHODS

Location: *Le Bec-Hellouin* (Normandie, France), oceanic climate
Studied soils: 3 soils managed with permaculture practices (*mounds*, *beds* and *forest garden*), 1 *pasture* representing **the situation of the three permaculture soils before cultivation (exact same location)** and 1 soil under conventional agriculture practices (2 km, **used as a reference** for conventional agriculture practices) ; three replicates made of three subsamples.

Site name	Pasture	Permaculture *mounds*	Permaculture *beds*	Permaculture *forest-garden*	Conventional
Characteristics of cultivation	/	Mound-cultivation ; very high maintenance	Beds cultivation ; very high maintenance	Vertical strata (tree, shrub, herbaceous); low maintenance	NPK fertilizers ; ploughing ; pesticides
Organic inputs nature	None	Horse manure	Horse manure	None	None (mineral fertilization)
Mean annual input ($t.ha^{-1}.yr^{-1}$)	/	225-330	225-330	/	/

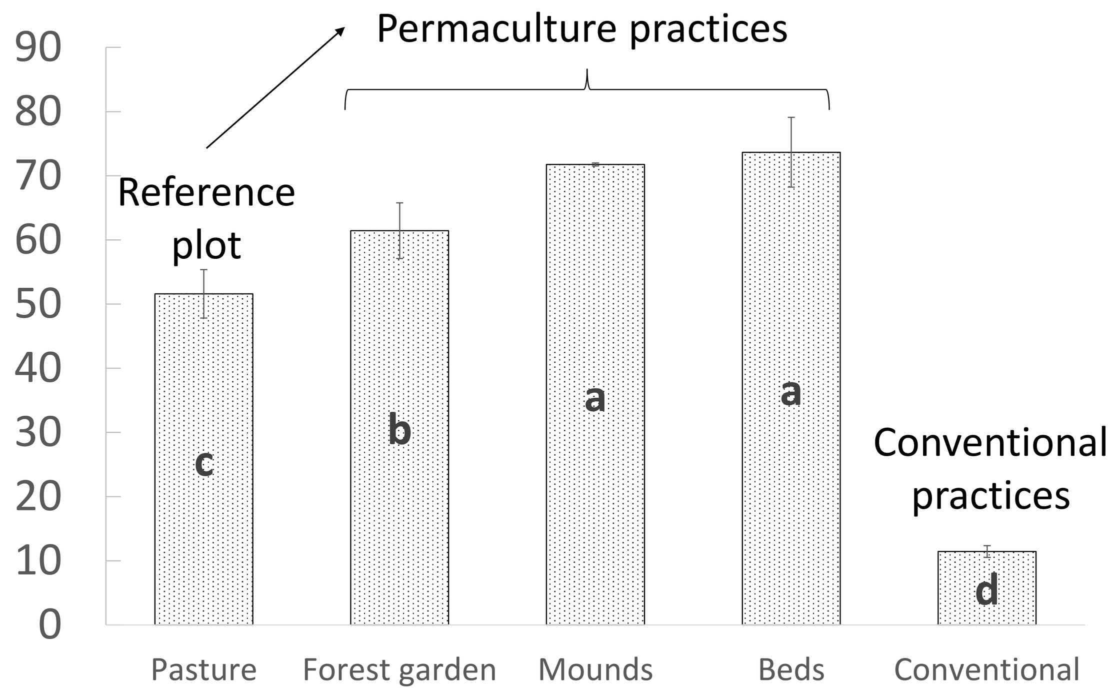
Soil characteristics: Bioavailable major nutrients (P, Ca, Mg, K) extracted with ammonium acetate-EDTA 1M; Cation Exchange Capacity (CEC) by Metson method ; OC & total N with a CN analyzer ; bulk soil densities (excavation method)
Soil aggregate-size classes separation (wet-sieving + 250-2000 µm fraction breakdown; Six et al. 1998; 2000):



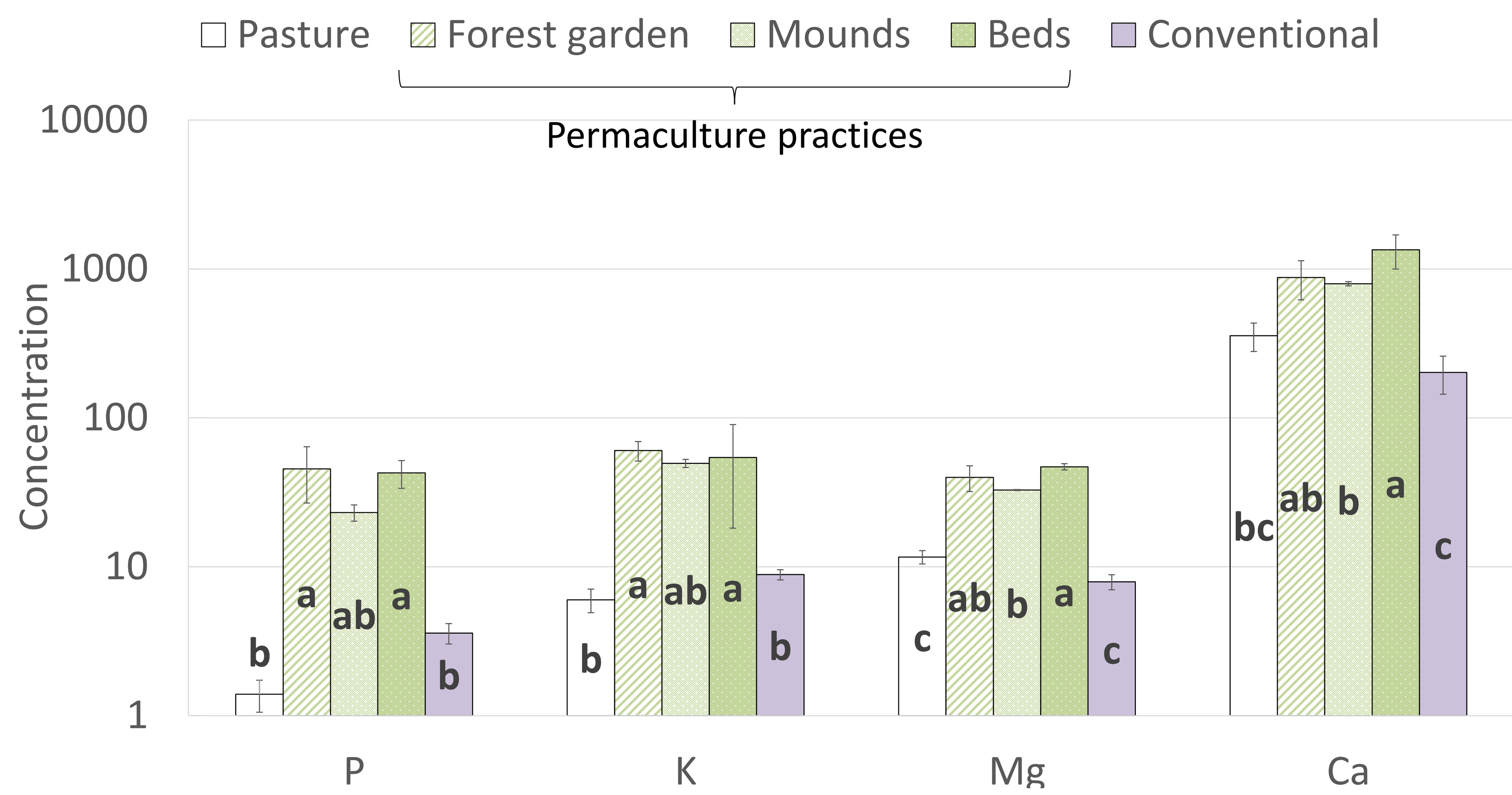
In order to combine aggregate-size distributions and their OC concentrations, we multiplied the mass percentage relative to bulk soil of each fraction by its OC concentration. It allows us to test the contribution of each fraction to the total OC stock, as shown on the right.

3 RESULTS

OC stocks increase ($Mg.ha^{-1}$)



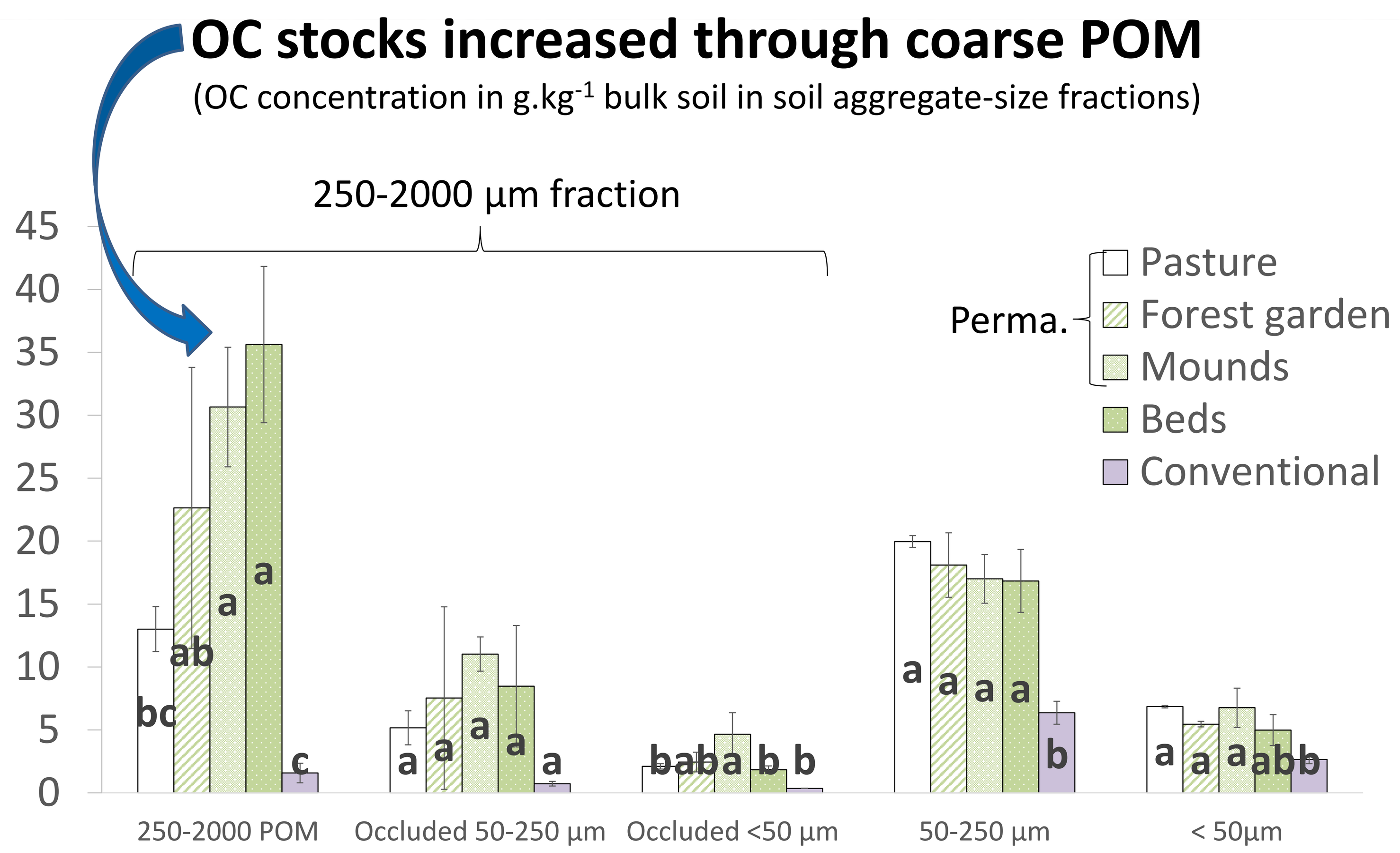
Bioavailable major nutrients increase ($mg.100g^{-1}$)



Total nitrogen concentrations were significantly higher in permaculture *mounds* and *beds* (6.2 and 6.3 $g.kg^{-1}$) compared to pasture (5.5 $g.kg^{-1}$) but not permaculture *forest garden* (5.8 $g.kg^{-1}$). **CEC** remains the same between the permaculture soils and the reference plot *pasture* (around 32 $cmol_c.kg^{-1}$).

OC stocks increased through coarse POM

(OC concentration in $g.kg^{-1}$ bulk soil in soil aggregate-size fractions)



4 DISCUSSION AND PERSPECTIVES

Permaculture practices strongly increased OC concentrations and stocks in soil compared to the initial state of soil pasture **through very large annual organic inputs (48 ‰ per year)**. Despite the absence of organic inputs in the *forest garden*, OC stocks remain higher compared to the reference parcel *pasture*, probably due the vertical stratification of the crops and the return of biomass through litterfall. In average, between 8% and 12% of the yearly inputs are stored.

The mineralization of organic amendments into the permaculture systems *mounds* and *beds* **releases a high amount of nutrients in soil solution.** The *forest garden* plot receives no organic amendments but shows concentrations of bioavailable nutrients as high as the others (with the exception of total nitrogen). This observation is probably due to (1) the smallest amount of biomass exports in this plot, and (2) a more developed root system due to the vertical strata system, stimulating the weathering of parent material and the return of nutrients with litterfall (Lucas 2001; Jobbagy & Jackson 2001).

The increase of OC stocks in the bulk soils is mainly due to the coarse POM content (which explains the non-increase of CEC), which represents a fraction less stable and more sensitive to mineralization in case of temperatures increase or land-use changes (Cheng et al. 2011; Poeplau et al. 2017). However, time since cultivation is probably too short to allow the progressive decomposition of the very large manure inputs applied by the farmers towards more reactive molecules associated with minerals. Another hypothesis could be the saturation of the permaculture soils leading to an increase of labile soil C fractions such as coarse POM, with a faster turnover (Gulde et al. 2008).

Further temporal research is needed to study the dynamic of this very large coarse POM pool and its potential ability to enhance macroaggregates rate and the formation of protected microaggregates in those (Six et al. 2000). Finally, a C balance should be performed at this scale, in order to determine if OC storage in cultivated plots corresponds to a net sink of CO_2 at the farm scale.

5 TAKE HOME MESSAGE

- **Permaculture practices could potentially constitute an interesting model for agricultural transition, but scientific data are scarce.**
- **The very large and localized organic inputs enhance OC stocks.**
- **The mineralization of amendments (or litterfall for the *forest garden* plot) enhances bioavailable nutrients concentrations.**
- **After 7 years of cultivation, the additional OC storage is mainly achieved through large particulate organic matter (POM), non-associated with minerals.**

REFERENCES

Stoate, C. et al., Environ. Manage. 2009, 91, 22–46 ; **Ferguson**, R. S. et al., Agron. Sustain. Dev. 2014, 34, 251–274 ; **Mollison**, B. et al., Tagari 1990 ; **Morel**, K. et al., Agric. Syst. 2017, 158, 39–49 ; **Six**, J. et al., Plant Soil 2002, 241, 155–176 ; **Six**, J. et al., Soil Biol. Biochem. 2000, 32, 2099–2103 ; **Dignac**, M.-F. et al., Agron. Sustain. Dev. 2017, 37, 14 ; **Lucas**, Y., Annu. Rev. Earth Planet. Sci. 2001, 29, 135–163 ; **Jobbagy**, E. G. et al., Biogeochemistry 2001, 53, 51–77 ; **Cheng**, X. et al., Biogeosciences 2011, 8, 1487–1498 ; **Poeplau**, C. et al., Glob. Chang. Biol. 2017, 23, 1316–1327 ; **Gulde**, S. et al., Soil Sci. Soc. Am. J. 2008, 72, 605 ; **Six**, J. et al., Soil Sci. Soc. Am. J. 1998, 62, 1367.