

## CAPACITY OF SOIL ANALOGUE FACING CLIMATE CHANGE: A TRUMP OR A JUMBLE?

### CAPACITÉ DES SOLS CONSTRUITS FACE AU CHANGEMENT CLIMATIQUE : ATOUT OU PROBLÈME?

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#### ABSTRACT

Constructed soils created from mineral materials mixed with composted biowaste are proposed as for urban land restoration. Their relevance under climate change lies in their capacity to regulate infiltration, water retention, drainage, and carbon storage under increasingly contrasted hydrometeorological conditions. However, the threshold beyond which added organic matter no longer improves these functions remains poorly quantified. This study investigated the response of a constructed silty soil to increasing carbon pool, with emphasis on hydraulic processes controlling soil–water transfer at plot scale. A four-month in situ experiment was conducted using a silty soil mixed with food-waste compost at 0, 5, 10, and 15% (v/v). Four 1 m<sup>2</sup> plots were exposed to natural rainfall conditions. Matrix Ks (saturated hydraulic conductivity) was measured using a Mini Disk infiltrometer, while effective Ks and available water capacity were estimated using the BEST approach. Laboratory analyses included bulk density, organic matter content, carbon and nitrogen contents, and laser granulometry before and after organic matter removal. Results showed that added compost modified hydraulic functioning more strongly than textural class. Effective Ks increased progressively with compost proportion, reaching values up to six times higher at 15% compost than in the unmixed control plot, indicating enhanced drainage through structural and macropore pathways. In contrast, matrix Ks exhibited limited temporal persistence. Available water capacity increased piercingly after the first amendment, from 3.71% to 5.32% at 5% compost, but showed no significant additional increase at 10 and 15%. No robust relationship was observed between colloid-associated organic matter and hydraulic response. Regarding carbon dynamics, considering the last field campaign, total carbon content was multiplied by 2.4, 2.9 and 3.1 between the control soil and composite ones, respectively. At the same time, the organic matter associated with the mineral colloidal fraction also increased, suggesting that the food-waste compost used in this study contained a relatively high proportion of recalcitrant carbon, which did not induce a strong short-term priming effect. These findings identify 5% compost as a functional threshold for this silty soil: beyond this level, gains in matrix Ks and water retention become marginal.

**Keywords:** Climate change; natural rainfall; bulk density; organic matter content; food-waste compost.

#### RESUME

Les sols synthétisés, construits à partir de matériaux minéraux mélangés avec des déchets biologiques compostés, sont proposés pour la restauration des sols urbains. Leur pertinence dans le contexte du changement climatique réside dans leur capacité à régler l'infiltration, la rétention d'eau, le drainage et le stockage du carbone dans le cadre des conditions hydrométéorologiques de plus en plus contrastées. Cependant, le seuil au-delà duquel l'ajout de matière organique n'améliore plus ces fonctions reste mal quantifié. Cette étude a examiné la réponse d'un sol limoneux construit à l'augmentation du stock de

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carbone, en mettant l'accent sur les processus hydrauliques régissant les transferts sol-eau à l'échelle de la parcelle. Une expérience in situ de quatre mois a été faite sur un sol limoneux mélangé avec le compost de déchets alimentaires à des concentrations de 0, 5, 10 et 15% (v/v). Quatre parcelles de 1 m<sup>2</sup> ont été exposées aux conditions pluviométriques naturelles. La conductivité hydraulique saturée (Ks de la matrice) a été mesurée à l'aide d'un infiltromètre Mini Disk, tandis que la conductivité hydraulique effective (Ks effective) et la capacité en eau disponible ont été estimées via l'approche BEST. Les analyses en laboratoire ont porté sur la densité apparente, la teneur en matière organique, les teneurs en carbone et en azote, ainsi que sur la granulométrie laser avant et après élimination de la matière organique. Les résultats ont montré que l'ajout de compost modifiait le fonctionnement hydraulique plus fortement que la classe texturale. La valeur de Ks effective a augmenté progressivement avec la proportion de compost, atteignant des valeurs jusqu'à six fois supérieures à 15% de compost par rapport à la parcelle témoin sans compost, ce qui indique un drainage amélioré par les voies structurales et de macropores. En revanche, la valeur Ks de la matrice a montré une persistance temporelle limitée. La capacité en eau disponible a augmenté de manière spectaculaire après le premier apport d'amendement, passant de 3,71% à 5,32% avec 5% de compost, mais n'a pas présenté l'augmentation supplémentaire significative à 10% et 15%. Aucune relation solide n'a été observée entre la matière organique associée aux colloïdes et la réponse hydraulique. En ce qui concerne la dynamique du carbone, selon la dernière campagne de terrain, la teneur totale en carbone a été multipliée par 2,4, 2,9 et 3,1 respectivement entre le sol témoin et les sols composites. En même temps, la matière organique associée à la fraction colloïdale minérale a également augmenté, ce qui suggère que le compost issu de déchets alimentaires utilisé dans cette étude contenait une proportion relativement élevée de carbone récalcitrant, qui n'a pas induit d'effet d'amorçage marqué à court terme. Ces résultats identifient un apport de 5% de compost comme seuil fonctionnel pour ce sol limoneux : au-delà de ce niveau, les gains en conductivité hydraulique saturée (Ks de la matrice) et en rétention d'eau deviennent marginaux.

**Mots-clés :** Changement climatique; Précipitations naturelles; Densité apparente; Teneur en matière organique; Compost des déchets alimentaires.

## INTRODUCTION

Human activities (sealing, agricultural overexploitation, pollution, etc.) increasingly produce waste, such as mineral waste excavated from construction projects and food waste (biowaste), and at the same time degrade the functional properties of soils (hydraulic, agronomic, environmental, etc.). This could lead to a deterioration in the level of health and well-being of society, a disruption of the balance of biodiversity and an acceleration of global warming. The collection and composting of food waste could enhance the value of biowaste on a city scale and produce compost of nutritional quality that complies with current standards as a soil amendment. It would be very strong economic issue for communities as part of the sustainable ecological transition to climate and demographic changes.

Composting is the controlled aerobic biological decomposition of organic matter into a stable, humus-like product called compost. Composting replicates natural decomposition but is enhanced and expedited by mixing organic waste with other ingredients to optimize microbial growth (Pergola et al., 2018). Composting bio-waste offers numerous benefits, including valorization, sterilization, stabilization, and reduction of waste biomass (Chia et al., 2020). It consists of the accelerated breakdown of organic matter by microorganisms under controlled conditions, typically characterized by a thermophilic stage that allows waste sanitation by eliminating pathogens (Lung et al., 2001). In addition, these composts can be mixed with mineral waste to produce in the end, constructed soils (consolidated and matured mixture of mineral and organic waste over the time) which is, among other actions, one of the most sustainable methods to give them back an active life. In addition, the constructed soil can indeed lead to the development of a real functional soil for the creation of green spaces (Pruvost, 2018; Snoussi et al., 2024) or as a support for urban agriculture (Araujo et al., 2017).

Furthermore, in a climatic context imposing increasingly frequent extreme hydrometeorological episodes, either through prolonged droughts and/or intense rains..., caused in part by climate change, in order to meet the needs of plants in water and nutrients and also ensure effective aeration and infiltration in the rainwater management structures (planted swales, etc.) filled by the constructed soils,

it is important that the soil can always maintain/improve its carbon sequestration capacity, water retention and water transfer functions. To do this, the main hydraulic properties (hydraulic conductivity and water retention capacity) of the soils must allow them to ensure their functions in an optimal, balanced and sustainable way.

The positive effects of compost application on soil properties has been summarized in the generous review done by Iraj et al., 2025. However, they alert that carbon sequestration claims require careful examination, with less than 10% of applied carbon remaining stabilized beyond five years (Aouass and Kenny, 2023), and high-carbon compost potentially increasing nitrous oxide emissions by 18-25% (Mengqi et al., 2023). Nevertheless, apart from some massif compost application rate in Mg/ha<sup>-1</sup>, they don't communicate a threshold to effectiveness of compost application rate.

Using regression analyses, Jong et al., 1983 then Hudson, 1994 and attempted to relate the variability in organic matter content (currently denoted by OM, in fact SOM) of the samples to the variability in the available water content. Existing developed models in agronomy do not consider the feedback effect of organic matter accumulation on water retention and saturated hydraulic conductivity (Rawls et al., 2004). As for carbon sequestration, Navarro-Pedreño et al., 2021 concluded that the addition of organic matter to soil could cause the liberation of carbon dioxide and organic wastes (compost...) and could also have no positive impact on soil properties.

In the case of carbon C, a disequilibrium between the input of plant C added to the soil and its decomposition rate results in changes in stored soil C (Curiel Yuste et al., 2007). A soil will give net C sequestration from increased C input if the organic C decomposition rate does not increase (Garten, 2009). Many studies demonstrate that soil C does not necessarily increase when organic C input from vegetation increases (Gill et al., 2002; Jones et al., 2003; Sayer et al., 2011; Xiao et al., 2007) and have shown that increasing the C input has a stimulating effect on C decomposition (Lai et al., 2013). Fresh organic C input can supply energy and nutrients for soil microbes, and can, therefore, accelerate soil organic C mineralization (Fontaine et al., 2003) which has called a "priming effect" (Bingeman et al., 1953). This process is mainly associated with stimulation of the microbes by the easily decomposable organic matter, and causes an increase in CO<sub>2</sub> efflux from soil into the atmosphere (Kuzakov et al., 2000).

At the same time, soil water content is also a considerable factor influencing carbon exchange and soil organic matter decomposition (Curiel Yuste et al., 2007; Xia and Wan, 2012). Microbial activity in soil needs a certain soil moisture, an aerobic medium some degrees of temperature. So, droughts could reduce the soil C lost by decreasing microbial decomposition of C in the soil.

Few studies have been conducted on the effects of climate change on the soil C cycle in the case of the implantation of the constructed soils exposed additionally to climate change effects (prolonged humid and dry periods). The elevated quantities of compost (organic matter) portion application in constructed soils could add huge amounts of organic C in the soil. The potential of C decomposition causing CO<sub>2</sub> efflux into atmosphere, by employing high organic-based constructed soils, accompanied by medium to high precipitations, could make contributed the constructed soil in global climate change. However, the relationship between C sequestration and increased precipitation is not clear. In the case of constructed soil, identifying the effect of added organic matter (enhancing leaching the C downward via poral soil water and/or increasing soil water content to enhance microbial activity) on soil carbon decomposition or sequestration is a real subject that could be tried to meet.

The "conservative hypothesis" first implies framing the question with a "pessimistic scenario" to find a solution that will mitigate a risk. relative to a "threshold" representing an "equilibrium", it would be considered as a limiting case (minimal or maximal, depending on the problem) through the selection of certain parameters.

So, in this study, it would be tried to understand the adverse effects of excessive added organic matter (via compost application) on soil functions, considering a pessimistic scenario. A threshold of Added Organic Matter at which the excess of OM still exists but does not destabilized the soil balance was

investigated. Consequently, the conservative hypothesis is an excess of OM acceptable with regard to the balance of the soil (for hydric functions and carbon sequestration).

## MATERIAL AND METHODS

The mineral-base material, a typical silty soil of the Paris Region in France (Silty Soil of Saclay), has been chosen for this study. This soil is almost well-known for its agricultural qualities. To boost its quality (pedological and physical) and correct some inadequacies, an urban food waste compost has been used to be mixed with it.

For this aim a 10 mm sieved food waste compost (COM) commercialized by a Parisian Startup has been used. After our initial laboratory tests, the food waste compost used in this research is characterized by total organic matter of  $59.33\pm 0.04$  and a pH of  $7.94\pm 0.001$  (moderately alkaline) and a C:N ratio of  $10.28\pm 0.10$ . To carry out the in situ physical tests and soil sampling, the implanted plots filled by the soil and compost mixtures were created and monitored over time. From now on, we will call this mixture "composite soil". The in-situ experimentation was realized on the available green space of the Regional Delegation of the French Institute for Development (IRD) situated in the suburb of Paris in France ( $02^{\circ}29'11.8''\text{E}$ ,  $48^{\circ}54'49.9''\text{N}$ ) by creating four plots of  $1\text{ m}^2$  in area ( $1\text{ m} \times 1\text{ m}$ ), with a depth of 40 cm from the natural terrain. These plots were converted from existing ones into composite soil filled ones, each in the 40cm-thick top horizon, to be investigated over 4 months.

This research aimed to establish plots with varying proportions of added organic matter (AOM) content derived from composted food waste. In order to slim any impact, four plots with 4 volumetric compost content of 0%, 5%, 10% and 15% and 4 volumetric soil mineral content of 100%, 95%, 90% and 85% of Silty Soil of Saclay were set up (P1 to P4 plots). Each plot has four different measurement points (A, B, C, and D). These four points were assessed over time, representing the 4 field campaigns. There was a three-week interval between two measurements. The first campaign sampled and tested point A of the four plots (in March 2024), while the last sampled and tested point D (in June 2024). Samples of the initial components (Silty Soil of Saclay and food waste compost) were also collected to determine their physical properties in the laboratory.

Each field campaign (4 in total) offered the opportunity to collect composite soil samples (bulk and undisturbed) and to carry out surface permeability tests at the right of each point. After realizing the in situ hydraulic tests, to carry out the laboratory tests on the different composite soils, 14 disturbed samples. During the monitoring period, the plots exposed the local natural meteorological conditions of an urban suburb area. But the leaves and branches fallen into the plots and the weeds grown in the plots were regularly weeded. In the middle of the measuring points, firstly, 14 permeability tests were done with a Mini-Disc infiltrometer device (Zhang, 1997) in order to estimate the matrix saturated hydraulic conductivity (Ks involved  $< 2\text{ mm}$  particles). Then, 14 BEST tests were realized to estimate the effective Ks (involved meso and macropores caused by stones, flora and fauna galleries + micropores caused by soil matrix) of the composite soil. BEST analysis (Lassabatère et al., 2006) were also used to estimate the available water capacity content ( $\Theta_{\text{AWC-BEST}}$ ) of the composite soil for each measuring point.

In the laboratory, the soil samples were treated and analyzed (Bulk density BD, real density  $\rho_s$ , organic matter content by combustion, pH, total nitrogen (N) and carbon (C) an Isotope Ratio Mass Spectrometer (Delta V plus) coupled with a Flash HT elemental analyzer (EA-IRMS, Thermo Fischer Scientific).

Hydrogen peroxide (33%) was used to remove organic matter of the samples. Finally, each dry sample after organic matter removal (OMR) was softly grinded to break sealing and coarse aggregates. The particle size distribution in the 2.0 mm sieved samples after and before organic matter removal (OMR), was then determined using the laser diffractometry particle size analysis (LDPSA) method (Mastersizer 3000, Malvern Company). Meanwhile, to study separate particle-size fractions from soil samples (before and after OMR), the four following fractions were separated using LDPSA: by decreasing particle size,  $2.0 - 0.05\text{ mm}$  (sand),  $0.05 - 0.002\text{ mm}$  (silt),  $0.002 - 0.001\text{ mm}$  (coarse clay), and  $< 0.001\text{ mm}$  (colloid).

## RESULTS

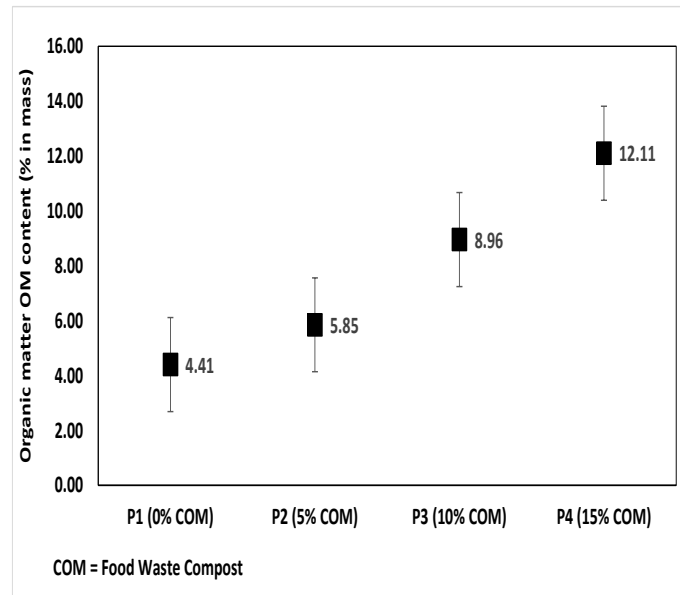
The average of measured organic matter mass content (by calcination) of each plot (average of 4 samples per plot, collected with three weeks interval) varied from 4.41% (P1) to 12.11% (P4), i.e. a progression of 2.75 times between P1 and P4. The average of measured Bulk Density BD, of each plot (average of 4 samples per plot) was, in g/cm<sup>3</sup>, 1.46 (P1), 1.21 (P2), 1.26 (P3) and 1.22 (P4), respectively. The Particle Density  $\rho_s$  of the samples in P1 filled with Silty soil of Saclay (0% of added compost) and the initial compost separately were 2.65 g/cm<sup>3</sup> and 1.67 g/cm<sup>3</sup>, respectively. The average Rock fragment content  $R_w$  (> 2 mm) of the samples were 32.32% (P1), 26.21% (P2), 31.52% (P3), 29.53% (P4) which do not follow any pattern.

The successive progression of organic matter content in function of compost proportion of each plot and also the similar and stable Bulk Density of the plots (with compost) confirms the good technical realization of the soil and compost mixtures (Silty soil of Saclay and food waste composted) and also correct execution (homogeneous compacting) of the plots. The Bulk Density of the plot without added compost (P1) was averagely 24% higher than the average of the Bulk Densities of the other three plots with added compost (P2 to P4) (

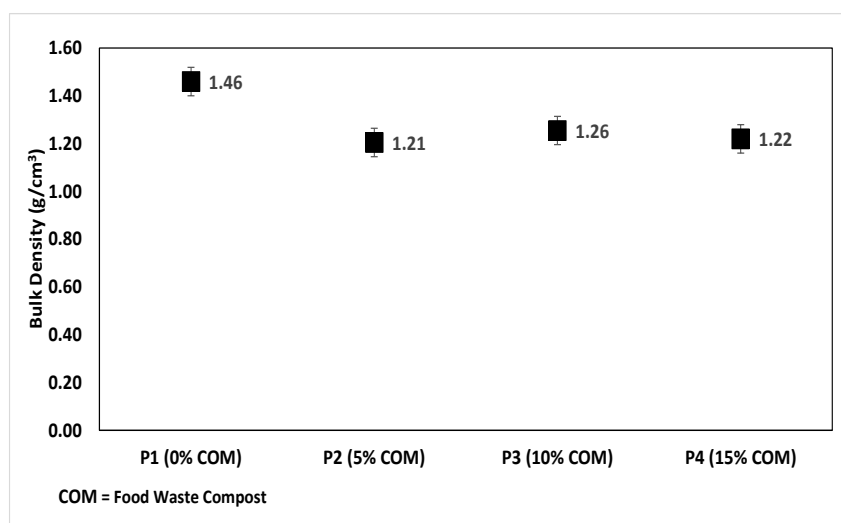
Figure 1 and  
Figure 2).

The pH values of the samples analyzed ranged from 7.34 to 8.52. Averagely, the samples of the plots with a proportion of compost in their composite soils (P2 to P4) were classed as “Moderately alkaline” and the plot without compost (Silty soil of Saclay P1) was classed “Slightly alkaline”. Classification established according to the US Department of Agriculture (Ditzler, C. et al., 2017). The pH moderately raised (around 8%) with the increase of the proportion of compost in the plots. Moreover, over four months of monitoring, the pH value of the composite soil of each plot decreased by 7%, averagely. At the same time, the C:N ratio reduces progressively by 20% with the increase in the compost proportion in the plots. The pH and the C:N ratio allow for a good biological activity of the composite soils in the plots. The details of these properties are recapitulated in the

Table 1.



**Figure 1.** Organic Matter mass content OM (obtained by standard calcination method) range of the plots (P1 to P4 - Average of 4 campaigns per plot over time)



**Figure 2.** Bulk Density (g/cm<sup>3</sup>) range of the plots (P1 to P4 - Average of 4 campaigns per plot over time)

| Plot            | No. Sample | OM by Calcination (mass %) | BD (g/cm <sup>3</sup> ) | Rw %  | pH   | Carbon C % | Nitrogen N % | C:N   |
|-----------------|------------|----------------------------|-------------------------|-------|------|------------|--------------|-------|
| P1<br>(0% COM)  | P1.A       | 4.49                       | 1.46                    | 37.41 | 7.88 | 1.03       | 0.099        | 10.41 |
|                 | P1.D       | 4.32                       | 1.46                    | 27.23 | 7.34 | 0.92       | 0.095        | 9.67  |
| P2<br>5% COM)   | P2.A       | 6.47                       | 1.19                    | 26.93 | 8.02 | 1.85       | 0.175        | 10.52 |
|                 | P2.B       | 5.71                       | 1.11                    | 26.46 | 8.22 | 1.49       | 0.145        | 10.32 |
|                 | P2.C       | 6.29                       | 1.28                    | 26.91 | 7.72 | 1.89       | 0.147        | 12.79 |
|                 | P2.D       | 4.94                       | 1.13                    | 24.55 | 7.89 | 2.18       | 0.177        | 12.33 |
| P3<br>(10% COM) | P3.A       | 9.61                       | 1.23                    | 33.83 | 8.10 | 2.38       | 0.257        | 9.27  |
|                 | P3.B       | 8.25                       | 1.28                    | 33.53 | 8.52 | 1.81       | 0.150        | 10.32 |
|                 | P3.C       | 8.22                       | 1.35                    | 31.27 | 7.93 | 2.22       | 0.199        | 11.14 |
|                 | P3.D       | 9.75                       | 1.16                    | 27.43 | 7.89 | 2.70       | 0.305        | 8.84  |
| P4<br>15% COM)  | P4.A       | 10.31                      | 1.2                     | 28.75 | 8.30 | 2.49       | 0.268        | 9.28  |
|                 | P4.B       | 13.41                      | 1.21                    | 30.94 | 8.42 | 2.15       | 0.214        | 10.05 |
|                 | P4.C       | 12.53                      | 1.3                     | 28.46 | 8.17 | 2.25       | 0.213        | 10.56 |
|                 | P4.D       | 12.17                      | 1.14                    | 29.98 | 7.98 | 2.87       | 0.340        | 8.47  |

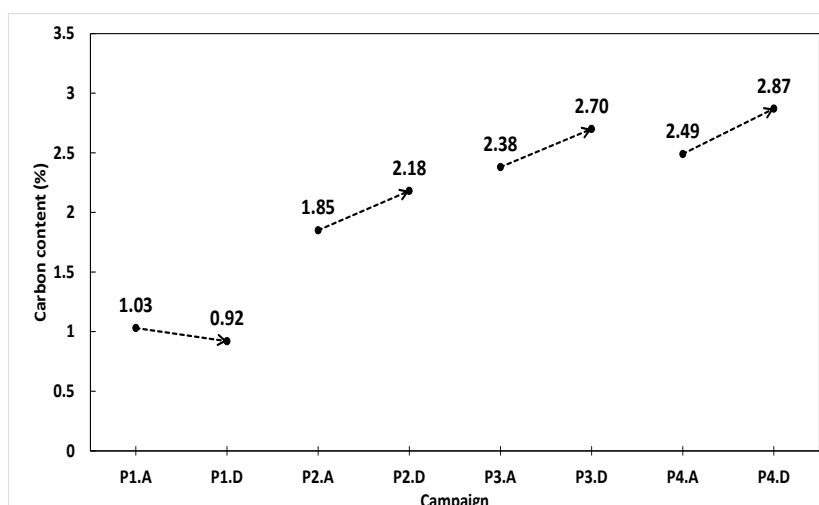
**Table 1.** physical and chemical measured parameters of the composite soils in plots (P1 to P4)

Using the laser diffractometry particle size analysis (LDPSA) method, the fractions of the particles of each sample in percentage (2–0.05 mm, 0.05–0.002 mm, 0.002–0.001 mm and < 0.001 mm), before and after OMR were measured. Also, the total mass content of removed organic matter (OM) of each sample was measured and converted from the volumetric percentage of the particle fractions before (mixed organic and mineral particles) and after OMR (mineral particles) in the sample. The total organic matter was distributed among particle size fractions under the assumption of a constant organic matter rate (Pro rata) in all four fractions equal to OM. In this way, each mineral particle size fraction had an allocated organic matter component.

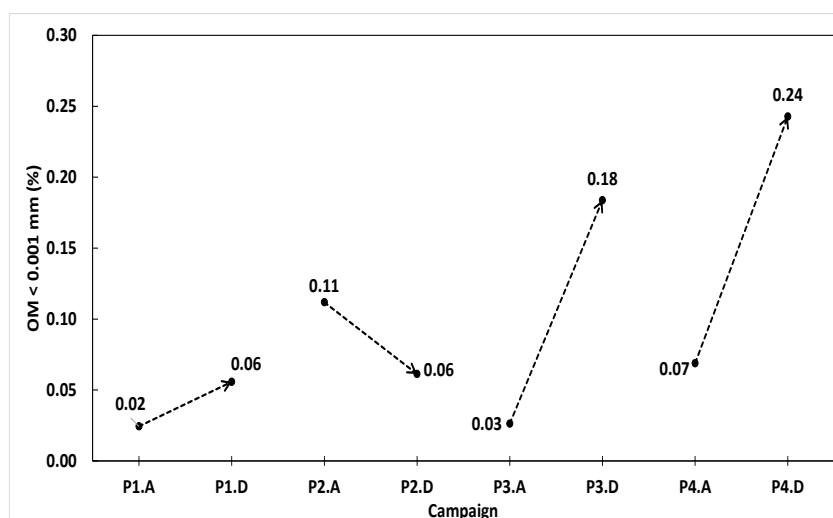
By including an organic matter fraction as the fifth fraction of the total sample mass, mineral fractions in samples before and after OMR have been recalculated on 5 fractions to allow for straightforward comparison and subtraction.

From a chronological view point, the Carbon content (C%) of the samples increased with the AOM (compost) between the first and last measurement campaigns (A and D) and for all plots (P1 to P4) (

Figure 3). The carbon content of P1 (with no AOM) lightly decrease between 2 campaigns. At the same time, the OM allocated to the colloid size soil fraction (< 0.001 mm) was also followed the same pattern for P1, P3 and P4 – except for the P2 which has a descending trend (Figure 4).



**Figure 3.** Carbon mass content C range of the plots (P1 to P4 – terrain campaigns A and D)



**Figure 4.** Organic Matter allocated to colloidal fraction size (< 0.001 mm) range of the plots (P1 to P4 – terrain campaigns A and D)

For estimating the hydraulic parameters of the soil, Mini Disc method was used to measure the matrix hydraulic conductivity (controlled by the particles < 2 mm, so mainly micropores of the soil) and BEST method was employed to estimate the effective hydraulic conductivity (controlled by all soil particles, < and > 2 mm, so macropores caused by stones, fauna galleries (in our case) mixed up with mesopores and micropores created by soil matrix) and total available water capacity content of the soil.

According to this base, the calculated saturated hydraulic conductivities (matrix Ks-MDisc and effective Ks-BEST) and the available water capacity (AWC-BEST) (volumetric content as %) for the 14 soil

samples (included silty soil without compost addition) are presented in **Error! Reference source not found.**

**Table 2.** Measured hydraulic property parameters of the composite soils in plots (P1 to P4)

| Plot            | No. Sample | Field Saturated Hydraulic Conductivity Ks (m/s) |                        | Available Water Capacity $\Theta_{AWC}$ (%) |
|-----------------|------------|-------------------------------------------------|------------------------|---------------------------------------------|
|                 |            | Ks-MDisc (matrix Ks)                            | Ks-BEST (effective Ks) | Calculated by BEST method                   |
| P1<br>(0% COM)  | P1.A       | 1.38E-06                                        | 7.38E-06               | 2.11                                        |
|                 | P1.D       | 2.19E-06                                        | 4.93E-05               | 5.30                                        |
| P2<br>5% COM)   | P2.A       | 5.54E-06                                        | 1.45E-04               | 5.09                                        |
|                 | P2.B       | 1.26E-06                                        | 6.11E-05               | 5.49                                        |
|                 | P2.C       | 2.00E-06                                        | 1.97E-04               | 4.70                                        |
|                 | P2.D       | 1.47E-06                                        | 5.00E-05               | 5.98                                        |
| P3<br>(10% COM) | P3.A       | 5.60E-06                                        | 5.52E-05               | 7.21                                        |
|                 | P3.B       | 2.20E-06                                        | 7.00E-05               | 4.74                                        |
|                 | P3.C       | 3.55E-06                                        | 1.29E-04               | 4.54                                        |
|                 | P3.D       | 1.74E-06                                        | 4.75E-05               | 4.54                                        |
| P4<br>15% COM)  | P4.A       | 7.33E-06                                        | 9.88E-05               | 7.16                                        |
|                 | P4.B       | 7.58E-06                                        | 1.71E-04               | 5.54                                        |
|                 | P4.C       | 3.54E-06                                        | 3.14E-04               | 4.86                                        |
|                 | P4.D       | 1.67E-06                                        | 9.85E-05               | 4.58                                        |

The Ks-MDisc (related to micropores) ranged from  $1.26 \times 10^{-6}$  m/s to  $7.58 \times 10^{-6}$  m/s, with a mean value of  $3.36 \times 10^{-6}$  m/s and a standard deviation of  $2.24 \times 10^{-6}$  m/s. The average of Ks-MDisc of each plot varied from  $1.78 \times 10^{-6}$  m/s (P1: 0% of compost) to  $5.03 \times 10^{-6}$  m/s (P4: 15% of compost). The ratio of the last two values ( $5.03/1.78$ ) is 2.82. While adding waste compost ((15% as volume) could improve the Ks related to the soil matrix ( $< 2$  mm) up to 3 times in average, with also a progressive raise of matrix Ks with the intermediate compost content in plots 2 and 3, this impact is neglectable for all four plots, comparing the first (A) et the last (D) (

Figure 5-a).

The mean effective Ks is about 32 times higher than the matrix Ks. Indeed, the Ks-BEST (related to all composite soil pores) varied from  $7.38 \times 10^{-6}$  m/s to  $3.14 \times 10^{-4}$  m/s, with a mean value of  $1.07 \times 10^{-4}$  m/s and a standard deviation of  $8.42 \times 10^{-5}$  m/s. The average of Ks-BEST of each plot ranged from  $2.84 \times 10^{-5}$  m/s (P1 – 0% of compost) to  $1.71 \times 10^{-4}$  m/s (P4 – 15% of compost). The ratio of the last two values ( $1.71/0.284$ ) is 6.02. In spite of Ks-MDisc, adding food waste compost (15%) could improve the effective Ks related to all soil pores ( $<$  and  $> 2$  mm) up to 6 times in average and also improve the effective Ks comparing the first (A) et the last (D) (

Figure 5-b).

In both types of Ks, the positive impact of adding compost on hydraulic conductivity (transfer function) was observed as soon as the first light amendment with compost (P1: 5% of the compost as volume) but this impact increases progressively with the increase in the percentage of compost only for the effective Ks and not for the matrix Ks. The influence of compost on the improvement of the transfer function of the composite soil related to matrix Ks, seems to be negligible at the end of the four-month

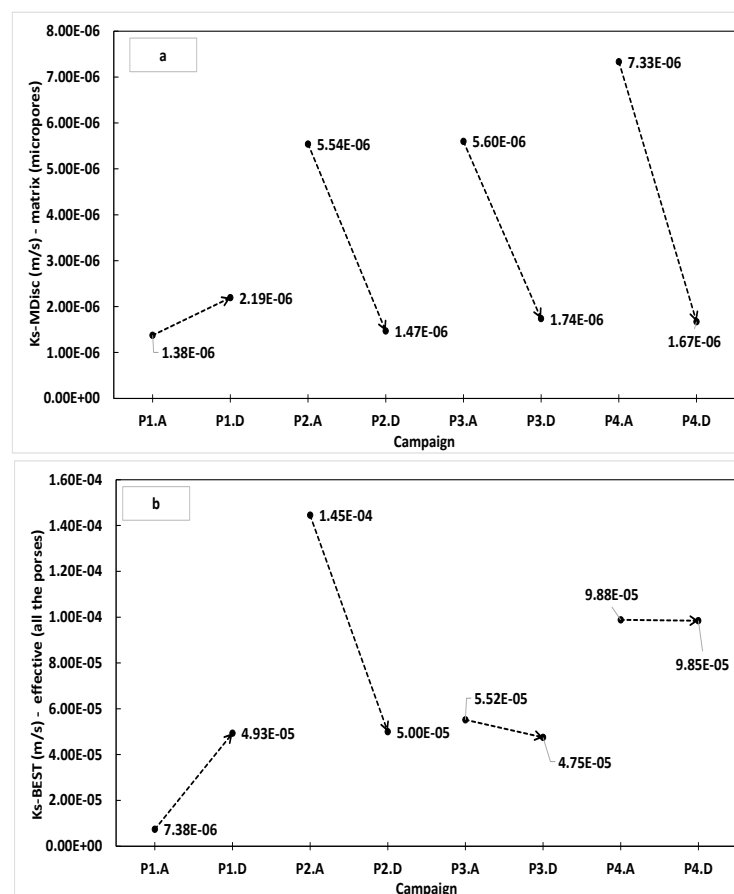
monitoring but efficient in the case of effective Ks (13 times for effective Ks comparing Last (D) campaigns).

At the same time, for the 14 samples, the estimated total available water capacity volumetric content ( $\Theta_{AWC\%-BEST}$ ) ranged from 2.11% to 7.21% with a mean value of 5.13% and a standard deviation of 1.24%. The averages of  $\Theta_{AWC\%-BEST}$  for each plot were 3.71% (P1), 5.32% (P2), 5.25% (P3), 5.54% (P4). According to this result, after the first compost amendment (P2 with 5% of compost as volume) which coincides with an averagely increase of 45% on available water capacity comparing to the plot with 0% compost (P1), the second and third amendments (P3 with 10% and P4 with 15% of compost) have no significant impact on the available water capacity of the composite soil. In fact, AWC was not controlled by the compost rate. After four-month of monitoring, the available water capacity of the plots gets closer together between all for compost proportions, comparing the last (D) terrain campaign (

Figure 6). The results for AWC were consistent with the results for the BD of plots (cf. Figure 2). In reality, BD also influences effective Ks which means that higher BD consistently leads to lower effective Ks. This expected effect is observed in plot 1 and in plot 3.

By considering first (A) and last (D) campaigns, no significant impact of organic matter content allocated to colloid mineral fraction was observed on hydraulic properties (saturated hydraulic conductivity and available water capacity) of the composite soils (

Figure 7).



**Figure 5.** Hydraulic conductivity range of the plots: P1 to P4 - terrain campaigns A and D (a: matrix Ks variation, b: effective Ks variation)

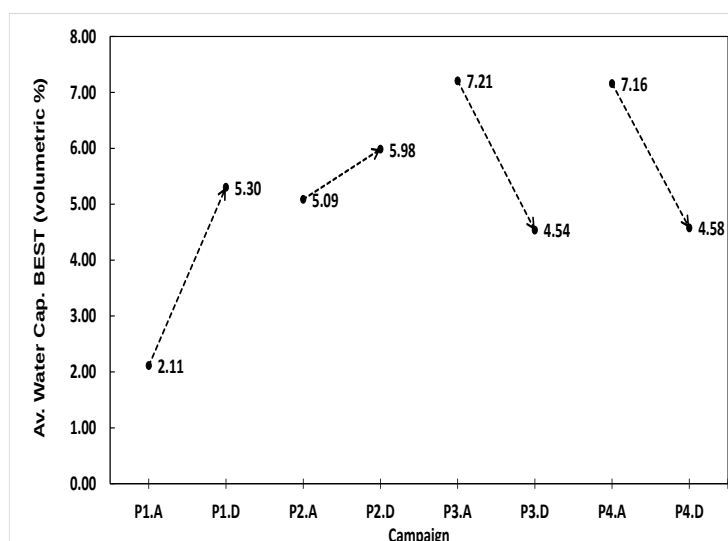


Figure 6. Available Water Capacity (θAWC%-BEST) range of the plots: P1 to P4 - terrain campaigns A and D

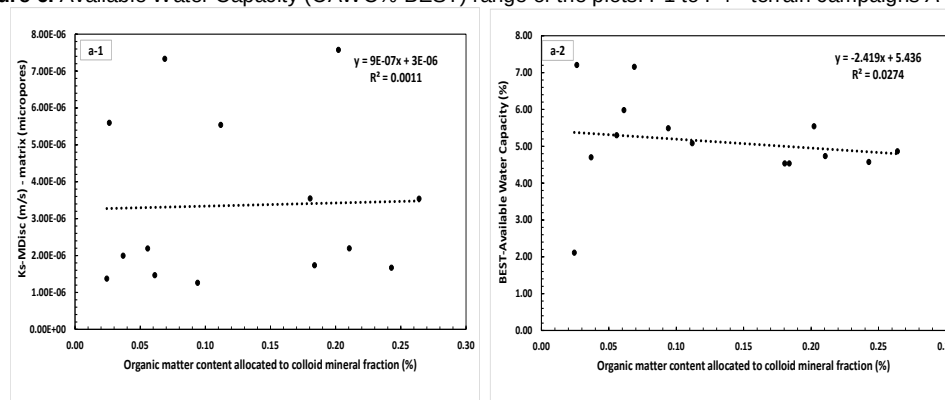


Figure 7. Correlation between the organic matter allocated to colloid mineral fraction of the samples and their Matrix Ks and AWC (a-1 and a-2)

## DISCUSSION AND CONCLUSION

From the macro-indicator point of view, the construction of composite soil by adding compost (AOM), did not changed the mineral textural classification (

Figure 8) of the composite soils during four-month monitoring and all the 14 samples were positioned in the *Coarse Loamy* class (13 *Silt Loam* and 1 *Sandy Loam*). So, four-month real state weathering of the composite soil with four propositions of AOM has no impact on the textural class of the soils.

The independence of the hydraulic conductivity from the ultra-fine (colloid) organic fraction existing in the composite soils could be considered as normal, because the organic matter content of the food waste compost contribute largely in sand and silt fraction increase and also the food waste compost contains about 30% of rock fragment (> 2 mm) which affect positively on effective Ks on heterogenous manner (Nasri et al., 2015). So an increase of colloid size OM during time has no impact on the matrix-related hydraulic conductivity.

The results showed that total soil water retention capacity increase with the first proportion of food waste compost (P2 – 5% of compost) but did not increase any further with more food waste compost in silty soil (cf.

Figure 6). Also, the observations proposed that the capacity of the composite soil to retain water could reach to its maximum since then on the first addition of the compost proportion. So, the relationship between the value (%) of the colloid mineral fraction and the organic matter content associated to this fraction could be an indicator for the soil water retention capacity. The results are consistent with the results of the mega analysis of (Minasny and McBratney, 2018) about the limited effect of the OM and its colloidal phase on retention capacity of the soils. Consequently, in the case of the retention and transfer function of the soil, 5% of added food compost (AOM), could be considered as the threshold for the effectiveness of compost application rate.

As for OM and so organic carbon content of the composite soils, while no temporal variation tendency was observed for four-month monitoring of four plots, but, considering the last (D) terrain campaign results, the total carbon content multiplied by 2.4, 2.9 and 3.1 between plot A (0% of COM) and plots B, C, D, respectively. In the same time, this ratio is 0, 3 and 4 for the OM associated to the mineral colloid size particles (OM < 0.001 mm). This result could be interpreted as that the used food-based compost contains much more recalcitrant carbon which did not cause the priming effect and could be considered as sustainable action to climate change which increases carbon sinking potential of soil and minimizes carbon emission. In contrary, according to Wang et al., 2022, when an organic amendment rich in labile carbon is incorporated into the soil, resulting in a positive priming effect and reduced microbial carbon use efficiency. This facilitates the decomposition of already stored carbon in the soil. So, the application of fresh organic amendment tends to promote the carbon emission source capacity of soil rather than sinking it.

So, the quality and type of carbon contained in added compost to the mineral based waste seems to be the key factor in carbon sequestration capacity of constructed soils. Addressing this will require paying attention to the nutritional and chemical compositions of an added organic matter to ensure that the right amount of recalcitrant carbon applied is higher than the labile ones.

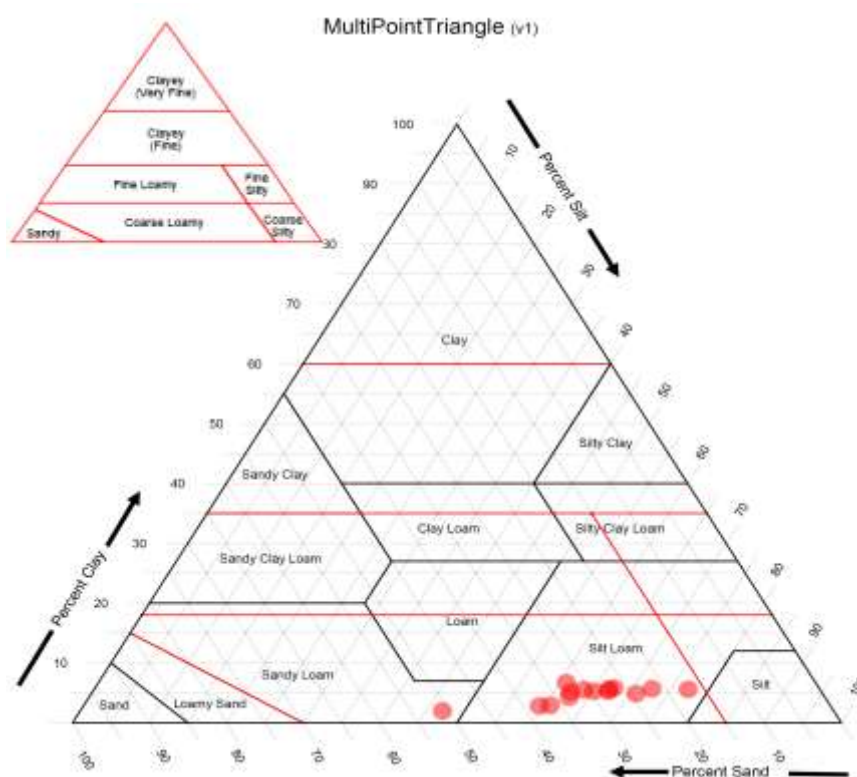


Figure 8. Soil texture triangle and textural class of the different 14 samples of the 4 plots.

Another major uncertainty in the prediction of soil carbon emissions following the application of organic amendment as its effect on the dynamics of microbial catabolic capacity tends to fluctuate with temperature and water availability. A most recent study conducted by Ye et al., 2024, observed that on one hand AOM reduces microbial catabolic capacity under field conditions, but warming on the other hand, increased microbial respiration and catabolic capacity. Enebe et al., 2025 cannot explain this phenom and wrote that the mechanism behind this variation in the effects of organic amendments in the field and laboratory is still unclear and necessitates expanding this research area to link laboratory studies to field conditions under environmental or climate change scenarios

Additionally, Smith, 2016 has defined as evidence of “sink saturation”, described that the potential of soils to sequester additional carbon may only exist for a limited period. by this Phenomenon, mineral surfaces available for binding and interacting with organic carbon become fully occupied with no available space to interact with newly added carbon. In the case of the composite soil in our study, it seems that colloidal surface increases with the compost proportion and would have not attain its sink saturation threshold, even at 15% of added compost. The duration of four-month monitoring seems to be not enough long to conclude a definitive result about sink saturation threshold effect. But, Berthelin et al., 2022 recapitulate that, over time, because of a well-known sink saturation effect “*threshold*”, the multiplier of added fresh organic carbon (crop residues) may even rise significantly above 10, up to a point when no net carbon sequestration takes place any longer. They added, the capacity of the soil sequesters carbon decreases over time and effectively vanishes ate the stage of “sink saturation and the time limit of sink saturation effect depends also to the soil type. Jenkinson D.S., 1990 observed in a sandy soil in the UK mineralization kinetics much faster than that depicted in Berthelin et al., 2022 may have been due in part to this sink saturation process.

This research showed that the type and quality of added organic matter seem to be the major controllers of carbon storage in constructed soils, because added organic matter richer in recalcitrant carbon are more likely to enhance carbon sinking potential, whereas ones dominated by labile carbon may stimulate microbial mineralization and promote carbon release. Consequently, the quality and biochemical composition of compost appear to be as important as its application rate when evaluating the climate-mitigation potential of constructed soils. Under the conservative framework adopted here, a moderate compost addition of about 5% represents a functional compromise, improving hydraulic regulation while avoiding excessive organic loading. This threshold-based interpretation provides a process-oriented basis for parameterizing plot-scale models of constructed soils and for supporting agroecological water management under climate variability. The interaction between application of composite soils and climate change therefore appears to be governed primarily by the balance between the type and composition of the added organic matter that influences micropore water storage and macropore water transfer and carbon storage in the soil.

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