ORGANIC MATTER STABILIZATION IN CONSTRUCTED SOILS MANUFACTURED WITH CLAY-RICH WASTE.

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Introduction

- **EU Soil Strategy**

  ➔ European soils to be restored, resilient and protected by 2050.

- **Proposal of a Directive on Soil Monitoring and Resilience (5 July 2023)**

- **Soil regeneration**

  - Objective: strengthening, restoring or creating the general or specific functionality of the soil compartment, by acting on the expected soil properties.
  - *“Regeneration brings degraded soils back to healthy condition”.*

EC 2021 : soil thematic strategy

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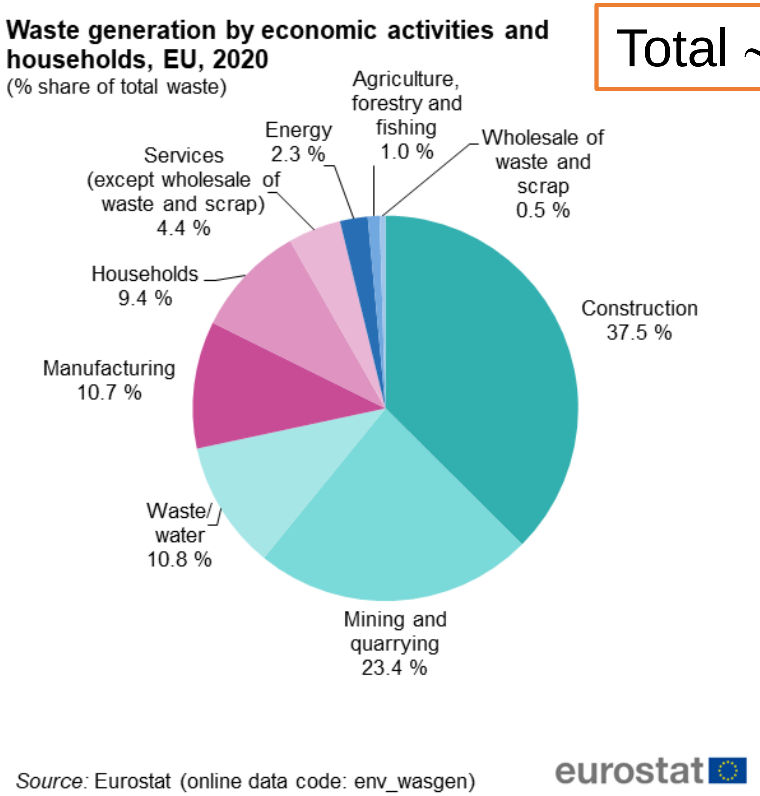
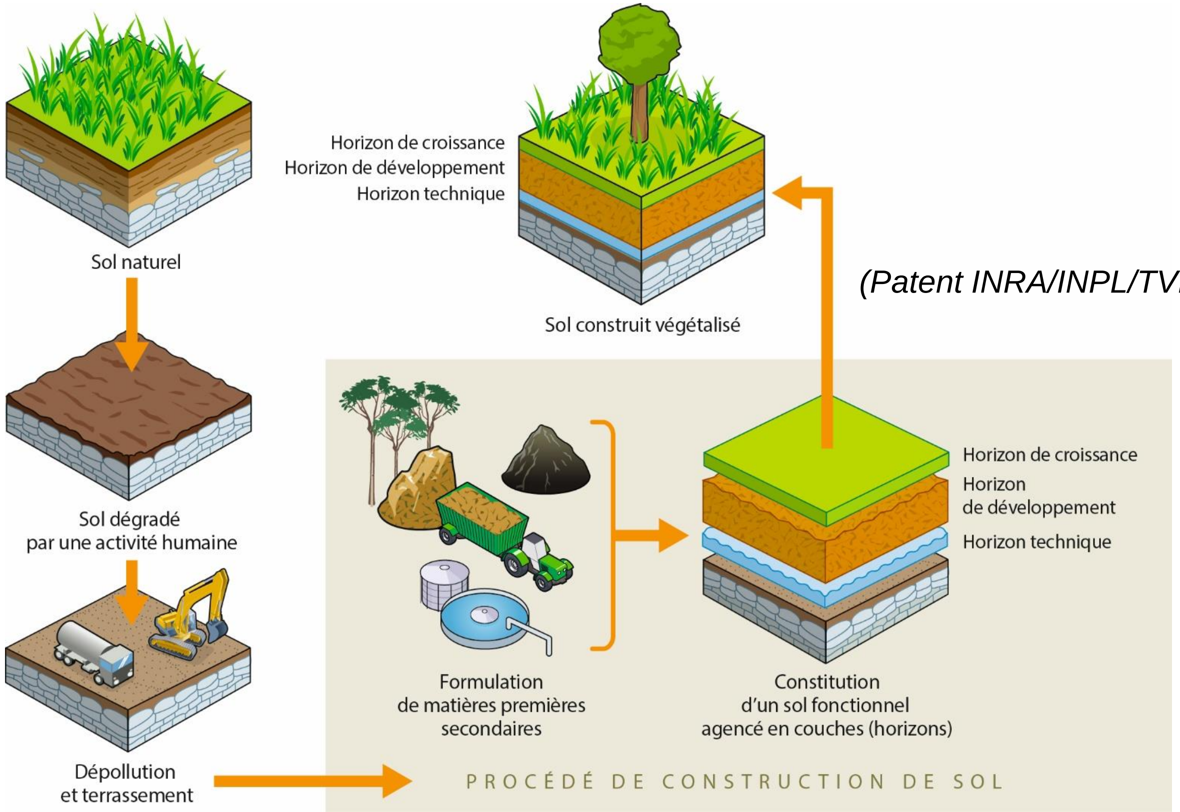
Introduction

- A solution for soil regeneration **: soil construction from waste** or **pedological engineering**



Total ~ **2,337 Mt**



(Patent INRA/INPL/TVD)

- Mainly used for the **regeneration of soils degraded by human activities (e.g. urban soils)** but can be transfered to **agricultural soils**

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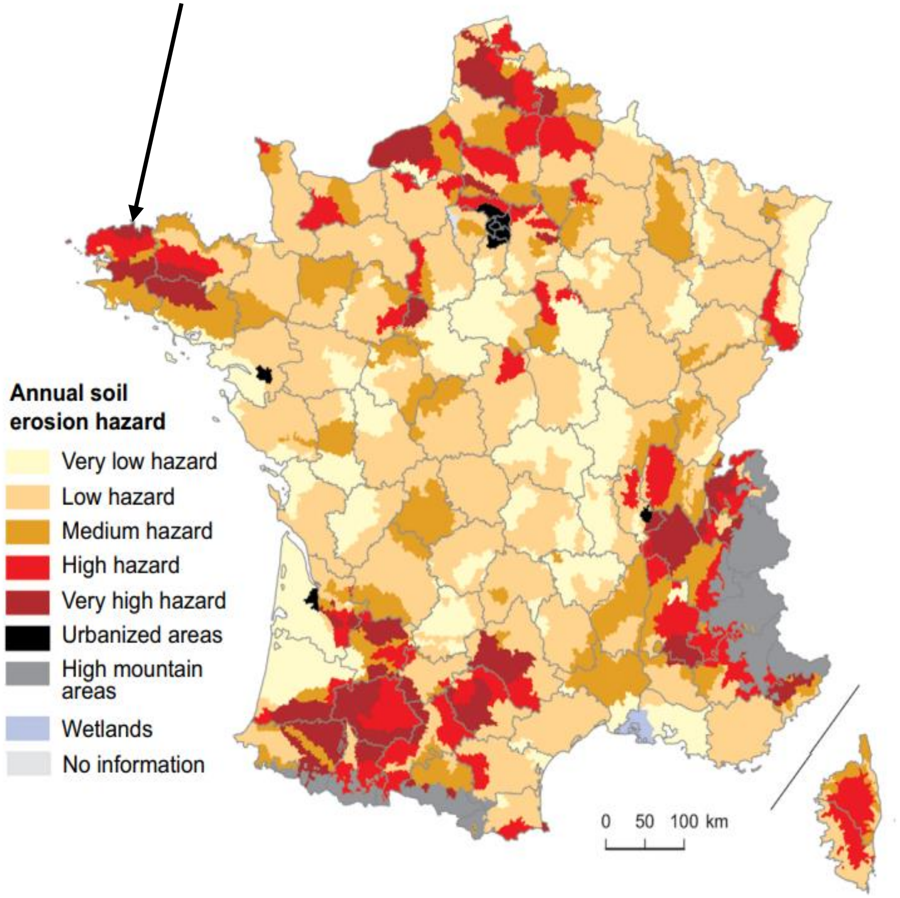
Context and Objectives

- **Context :**
  - Erosion mainly affects the loamy agricultural soils
  - Case study : agricultural soil from Caté experimental station (St-Pol-de-Léon, Brittany, France)

- **Objectives and research question :**
  - Can pedological engineering be used for agricultural soils to **improve their physical properties** and ensure **organic matter stabilization** ?
    - ✓ Hypothesis 1 : using clay waste improves soil aggregate stability;
    - ✓ Hypothesis 2 : using clay waste protects a proportion of soil organic matter from biogeochemical degradation.
  - Can **soil structure stability** be linked to **soil organic matter stabilization** ?

Experimental study (Caté experimental station)



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Materials and methods

- **Waste assessment and selection**
  - *Aggregate Washing Sludge* (AWS) from the washing process of a quarry
    - ✓ Mineralogical composition assessed by XRD (reactive minerals) : kaolinite (45%), interstratified illite/smectite (13%), illite (10%), smectite (0,8%), goethite (7%)

Storage ponds of aggregate washing sludge ©BRGM

  - *Compost* from green waste composting platform

- **2 soil recipes tested in plots (lysimeters) and one control modality**
  - 34 % AWS + 2.2 % compost + topsoil from Caté
  - 11 % AWS + 1.7% compost + topsoil from Caté
  - Control : 0.7% compost + topsoil from Caté

Materials and methods

- **Set-up of lysimeters**
  - 1) Process of preparing clay waste : suspension of clay waste (53% sludge, 47% water) in a concrete mixer
  - 2) Lysimeter filling with different soil recipes and mixing

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2

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  - 3) Placing all tanks outside and ploughing (4 lysimeters with different soil recipes, 2 of which are considered in this study + 2 control lysimeters).

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  - 4) Lettuce growing (3 crops)

4

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  - 4) Lettuce growing (3 crops)
  - 5) Soil structural stability, soil respiration and organic matter status measured after the last lettuce harvest.

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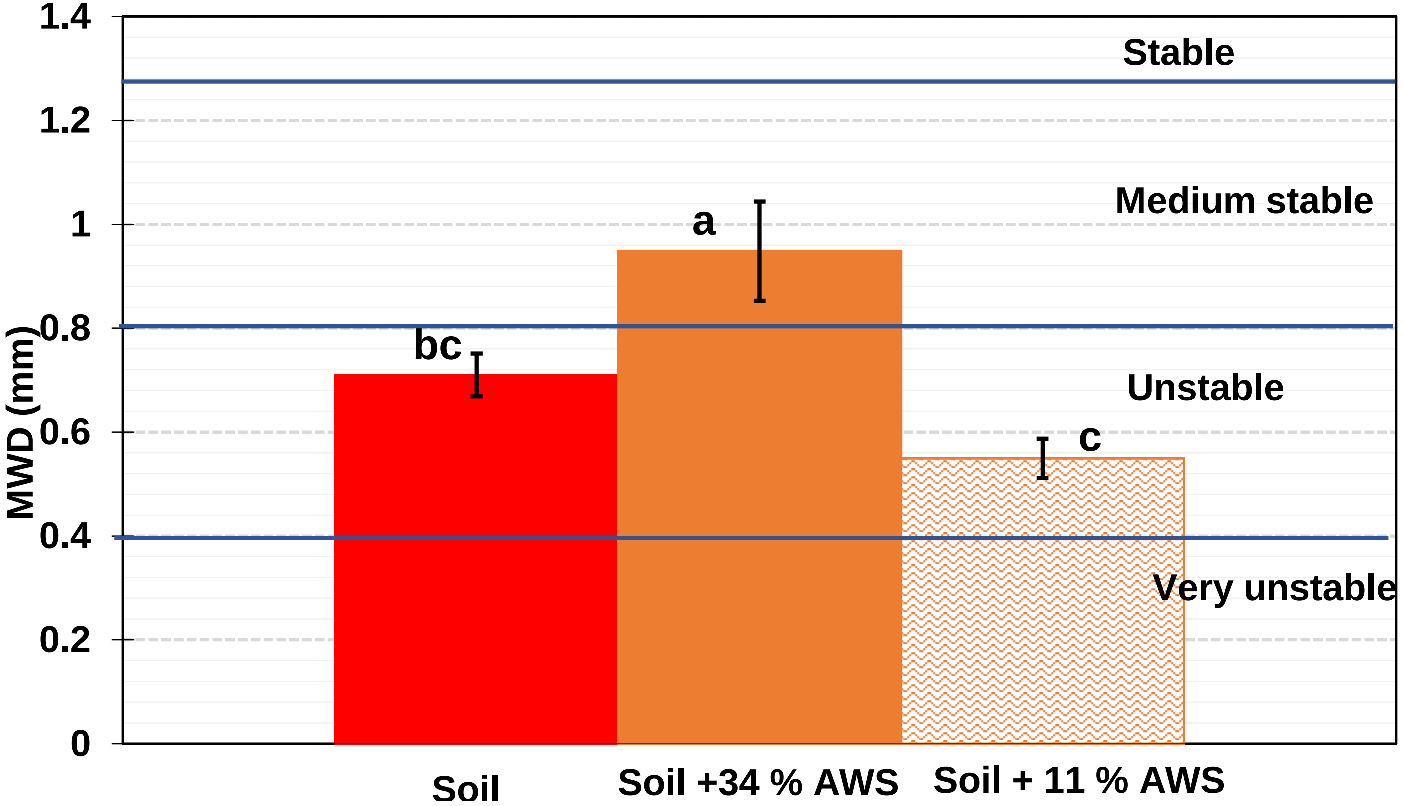
Materials and methods

- **Soil aggregate stability (NF EN ISO 10930, 2012)**
  - Treatment 1 : fast wetting by immersion of the aggregates to promote slaking
  - Treatment 2 : slow wetting to promote micro cracking by capillary action
  - Treatment 3 : mechanical breackdown of wet materials by agitation after immersion in ethanol
- **Organic matter stability (IFPEN, France)**
  - 1) Rock-Eval® 6 Turbo analysis : 4 samples x 3 replicates (12 analyses) ➔ uncertainty calculation based on analytical dispersion
  - 2) Thermogram processing and interpretation ➔ type and quality of OM
  - 3) Application of the SOTHIS method ➔ organic and inorganic carbon content
  - 4) Calculation of thermal stability parameters I-index and R-index ➔ thermal and biogeochemical stability of OM
- **In-situ soil respiration**
  - Accumulation chamber method with external recirculation (Echo Instruments, Slovenia).
  - Multiple quantifications (15) of the CO_2 flux in each plot
  - CO_2 monitoring with a Non-Dispersive Infra-Red (NDIR) detector (0 to 5000 ppmv ±2%).
  - Continuous monitoring of pressure, temperature and relative humidity inside the chamber.

Results

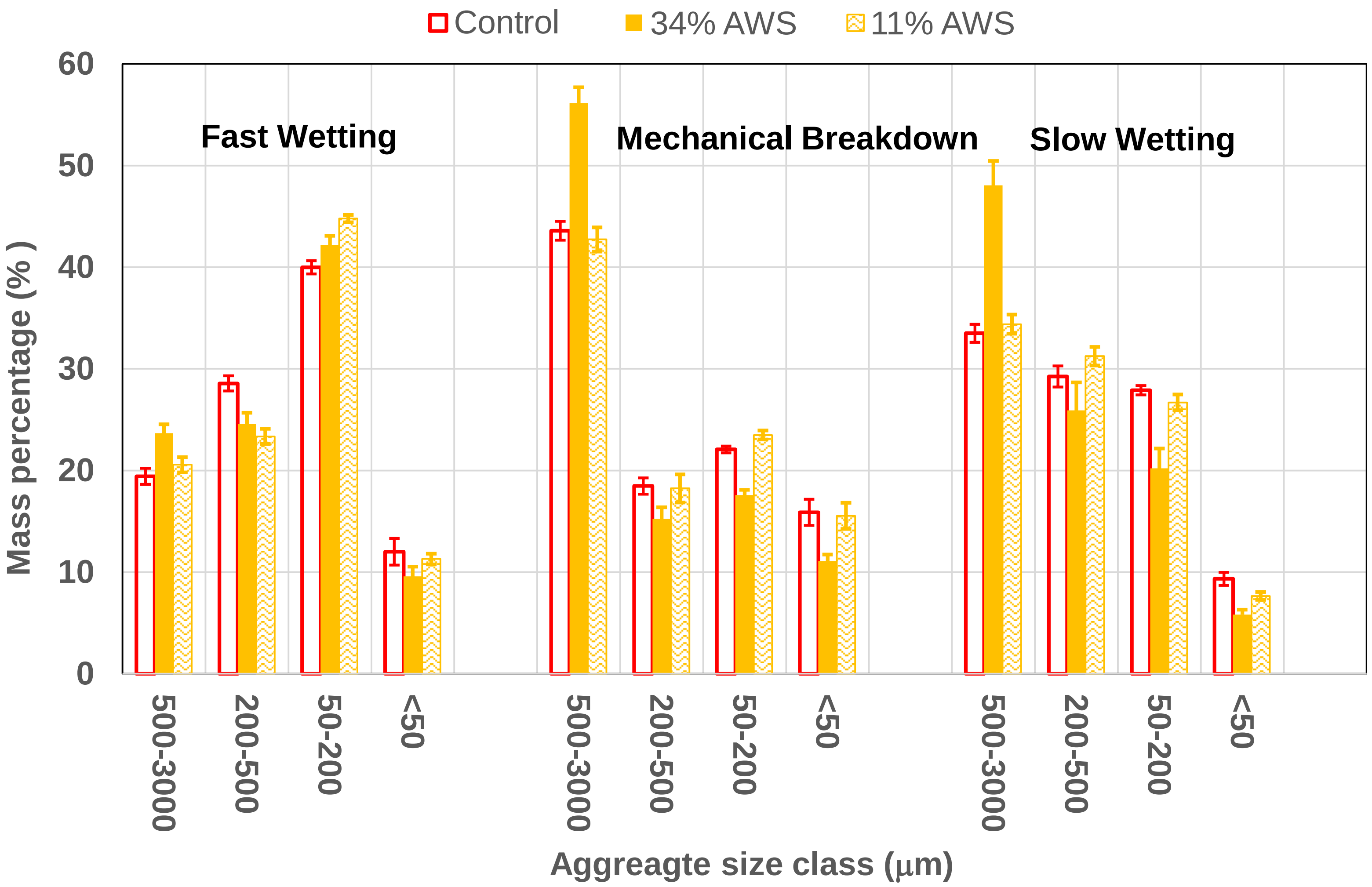
- **Soil aggregate stability**
  - Aggregates initially formed in the control soil are unstable;
  - Addition of AWS at a rate of 34 % **increases aggregate stability.**



Results

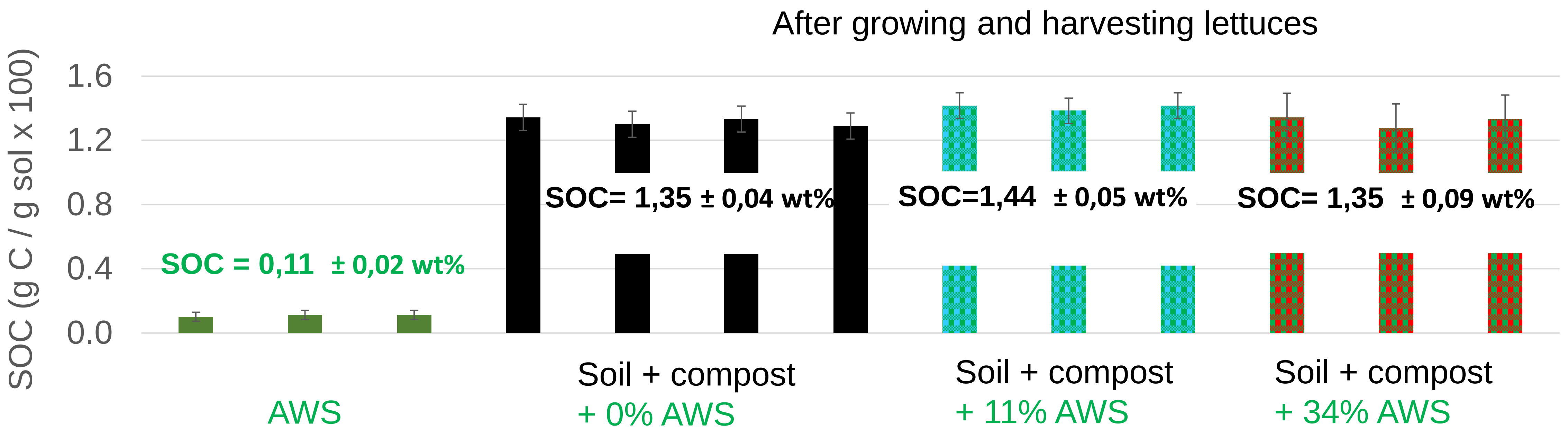
- **Soil aggregate stability**
  - Slow wetting and breakdown treatments: **higher proportion of stable macroaggregates** (500-3000 µm) in the modality with 34 % AWS

→ Addition of clay waste **increases macroaggregate stability**



Results

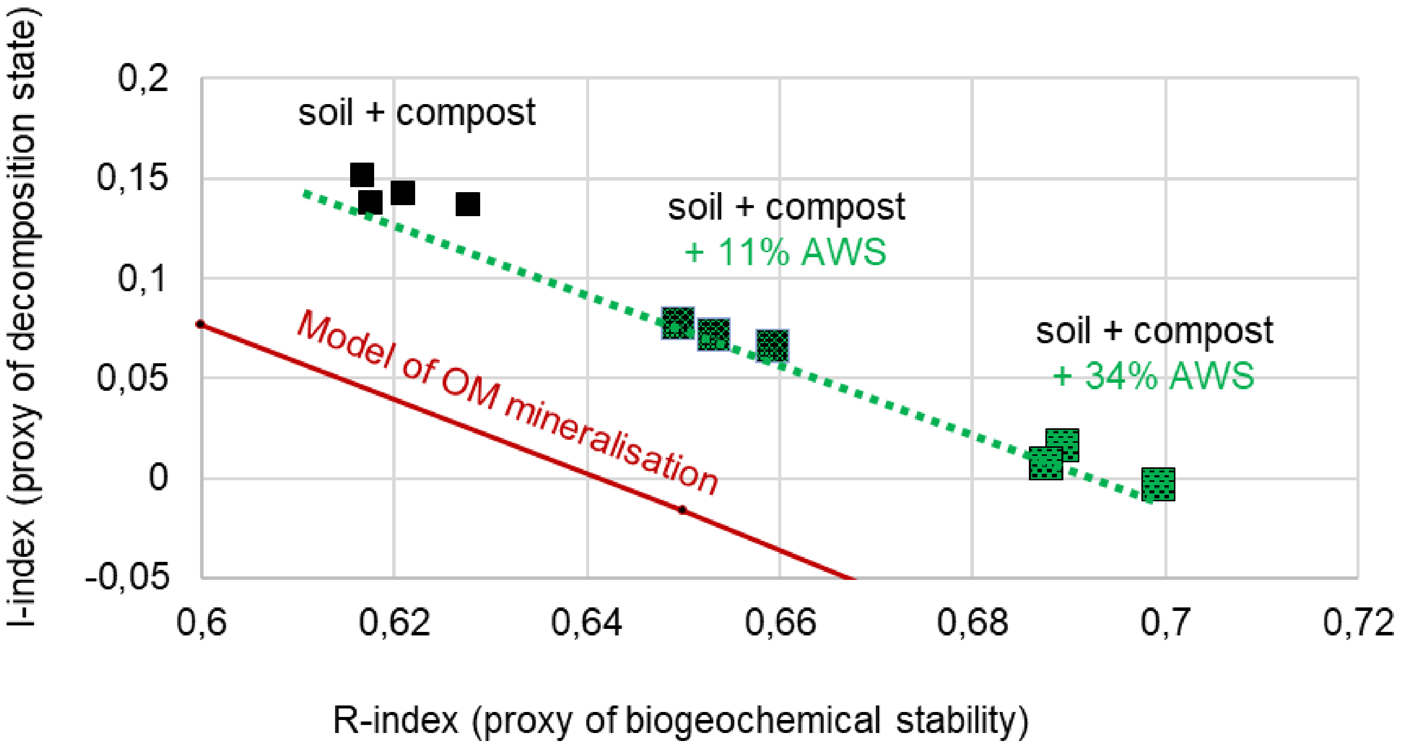
- **Soil organic carbon content (Rock-Eval® analysis)**



- **Organic carbon content is stable** between the modalities 0% AWS; + 11% AWS; + 34% AWS.
- The addition of compost in different proportions compensated for the dilution of organic matter by the aggregate washing sludge.

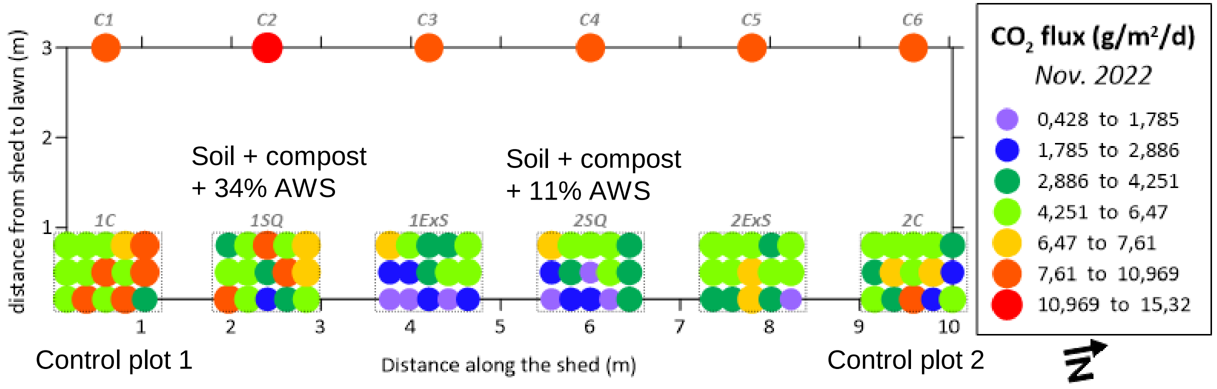
Results

- **Organic matter stability (Rock-Eval® analysis)**



- According to this parameters, **biogeochemical stability of OM after lettuce cultivation seem to increase with the amount of sludge added**, following the soil OM decomposition model.

- **In-situ soil respiration measurment**



	Nb. measures	f_{CO2} (g/m²/d)
Control plot 1	15	6.63 ± 1,72
Control plot 2	16 (1 repetition)	4.60 ± 1,90
Soil + compost + 11% AWS	16 (1 repetition)	3.50 ± 1,90
Soil + compost + 34% AWS	15	5.68 ± 2,34

- **No statistical difference** between the control plots and the studied modalities.
- Nevertheless, on average, aggregate washing sludge plots seem to emit 40% less (4 g/m²/d) than control plots (5.6 g/m²/d).
- **No direct relationship between the quantity of clay added and the flux**.

Conclusions

- **Soil structure**
  - Using clay waste improves soil aggregate stability
    - ✓ Higher proportion of stable macroaggregates for the recipe with 34% of AWS
    - ✓ A balanced mineralogical composition of clay minerals without too much smectite seems to improve macroaggregate stability, which is in line with literature (*e.g.* Denef et al., 2002; El Farricha, 2022).
    - ✓ The high content in iron (hydr)oxydes may also play a significant role in aggregate stability.

- **Soil organic matter stabilization**
  - Using clay waste seem to protect a proportion of soil organic matter from biogeochemical degradation.
  - However, there are still some unanswered questions:
    - ✓ Rock-Eval® : can results from thermal analysis be directly linked to biogeochemical degradation processes ?
    - ✓ In situ soil respiration measurements : this technique is highly sensitive to external parameters : e.g. meteorological parameters, soil moisture content.

- **Link between soil structural stability and soil organic matter stabilization**
  - Difficulty to prove this link in this study, even if this has already be studied (*e.g.* Six et al., 2000) → need for a complementary study, e.g. Rock-Eval® analysis of stable macroaggregate fractions.

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References and acknowledgement

- **References**

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