SSS9.4 Soil organic and inorganic carbon dynamics in agro-ecosystems

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Pyrogenic carbon redistribution in the landscape: example of a small, cultivated temperate watershed

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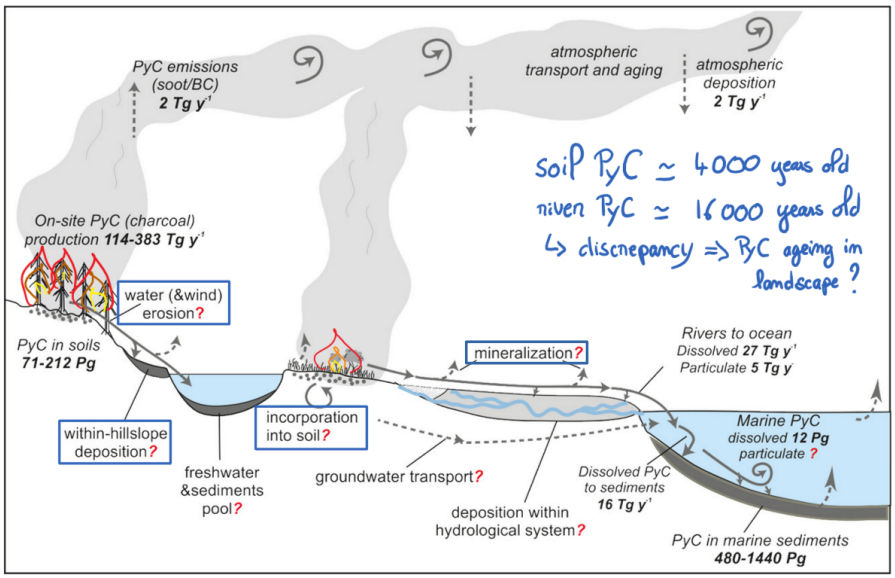
Introduction



Modified from Santín et al. *Global Change Biology,* 2016

Objectives

Study the **distribution** and **characteristics** of soil PyC through the landscape.

Hypotheses

1) PyC is translocated to soil **depth** (a) and **hill-foot** where it accumulates (b).

2) PyC at depth/hill-foot is **older** than PyC from other sites.

Pyrogenic carbon (PyC) is produced during fires under oxygen limiting conditions. It represents on average **15 % of organic carbon in soils**[1]. Its **residence time** in soils ranges from **50 to 1000 years**[2]. Over time PyC will undergo **transport** and **accumulation**. However, isolated measurements of PyC turnover time in surface soil horizons do not account for these **landscape scale processes**.

1. Reisser, M. et al. (2016) *Frontiers in Earth Science*

2. Singh, N. et al. (2012) *Biogeosciences*

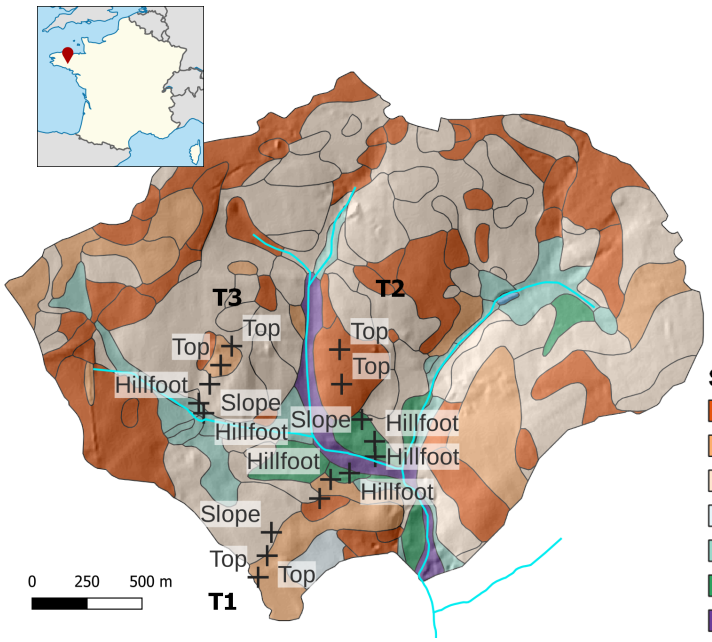
Age of river PyC (in the figure) from Coppola, A. I. et al. (2018) *Nature Geoscience*

Study site

- Naizin-Kervidy watershed, 4.9 km^2, mostly agricultural
- Instrumented and studied since the 90's as part of ORE AgrHys
- Part of the critical zone observatory network OZCAR

Location of the Kervidy-Naizin watershed in France. Modified from Location of Guadeloupe in France, TUBS, Wikimedia Commons, CC-BY-SA, version of 23 July 2011 https://commons.wikimedia.org/wiki/File:Guadeloupe_in_France.svg

Study site



- Soils developed on **siltstone** and **sandstone** overlayed by locally derived **loess**
- Gradient of soil development with proximity to the river.

Soil types
- BRUNISOLS
- BRUNISOLS-NEOLUVISOLS
- NEOLUVISOLS
- LUVISOLS typiques
- LUVISOLS-REDOXISOLS
- LUVISOLS DEGRADES-REDOXISOLS
- FLUVIOSOLS-REDOXISOLS

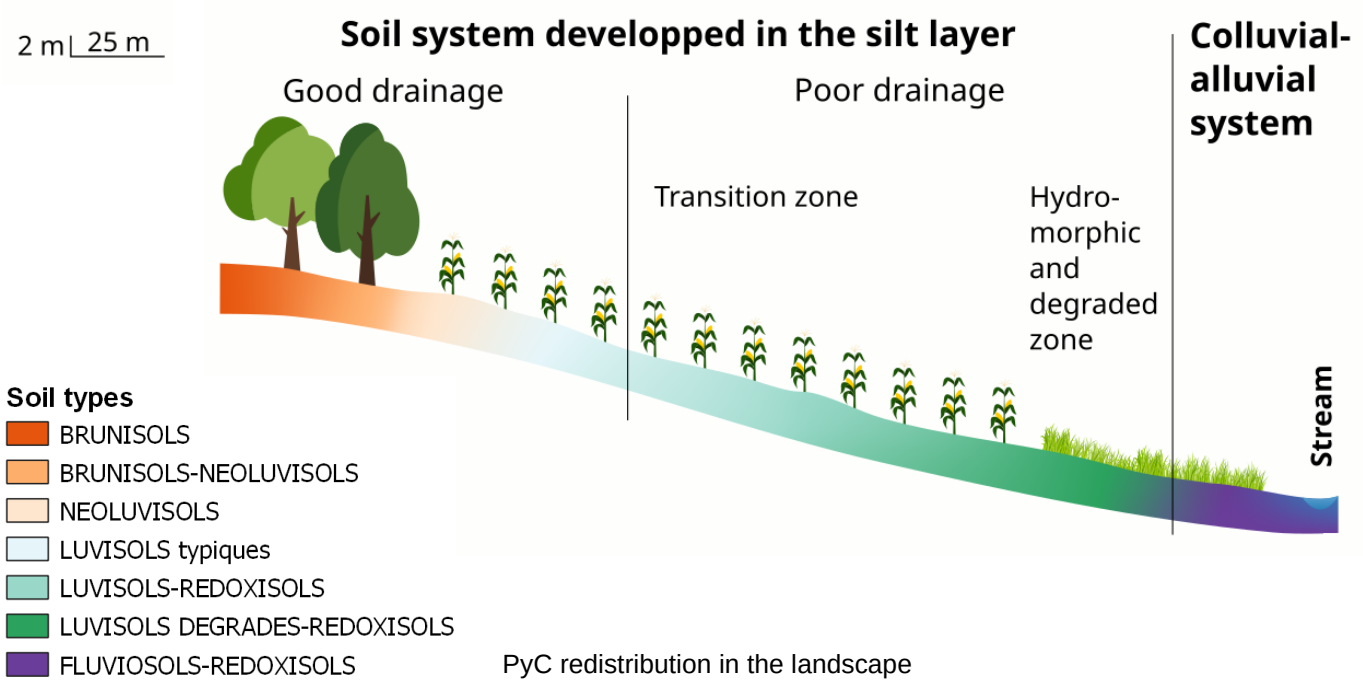
Other
- river Coët-Dan
- Sample sites
- Pond or reservoir

Soil units in the Kervidy area of the Coët-Dan watershed (ORE AgrHyS – Naizin).

Map drawn from UMR 1069 SAS INRA - Agrocampus Ouest original data downloaded from http://www6.inra.fr/ore_agrhys on 7 september 2022

Insert: location of study site in France (see slide 3)

Study site

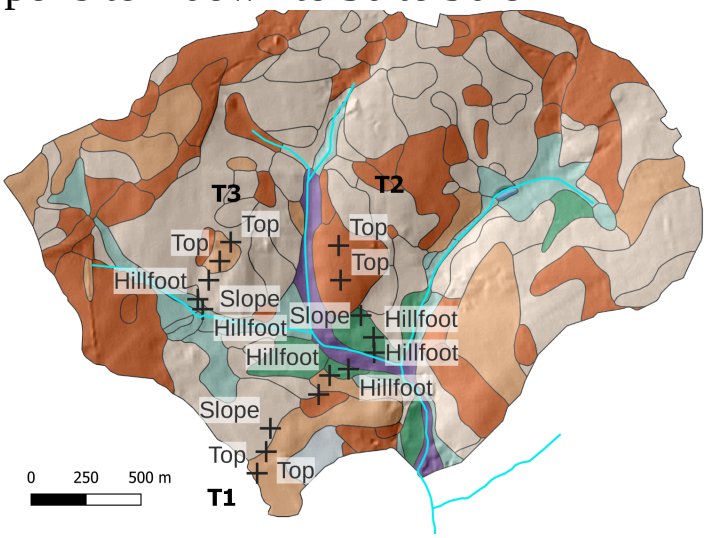


Organisation of soil units along a convex-concave slope in the Kervidy area of the Coët-Dan watershed. Vegetation as observed along transect 1 in June 2021.

Modified from Curmi, P. et al., in Cheverry C. (ed) (1998) *Agriculture intensive et qualité des eaux*, INRA

Material and methods

3 transects, 3 slope positions, 3 cores per site – down to 50 to 90 cm



Soil physico-chemical properties [Interquartile range]

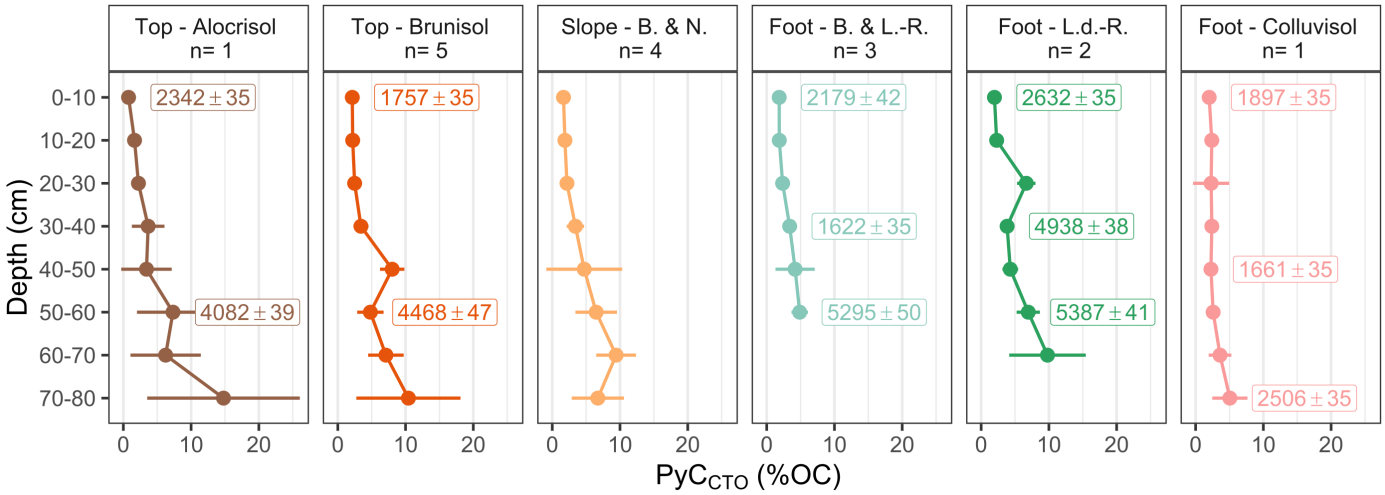
- OC_{tot} and $\delta^{13}C$
- PyC_{CTO}
- PyC_{HyPy} ^{14}C age
- Soil texture, pH, CEC, N, P and K content
- Iron oxides (oxalate and DCB)
- Fine earth fraction

Soil units in the Kervidy area of the Coët-Dan watershed (ORE AgrHyS – Naizin).

Map drawn from UMR 1069 SAS INRA - Agrocampus Ouest original data downloaded from http://www6.inra.fr/ore_agrhys on 7 september 2022

All soils were dried at 40°C, sieved at 2 mm and grinded in a ball mill. OC_{tot} and $\delta^{13}C$ were measured on a Picarro G2101-i Isotopic CO_2. PyC_{CTO} was measured following Agarwal and Bucheli, *Environmental Pollution*, 2011. PyC_{HyPy} ^{14}C ages were measured following Ascough et al., *Radiocarbon*, 2010. Soil texture, pH, CEC, total N, P and K content, total iron and Tamm (oxalate) and Mehra-Jackson (DCB) extracted iron were determined by Laboratoire d'Analyse des Sols, INRAE following their standard procedures. Fine earth fraction was determined from undisturbed cores applying corrections as in Peoplau, Vos & Don, *SOIL*, 2017

Results and discussion: PyC vs. bulk SOC

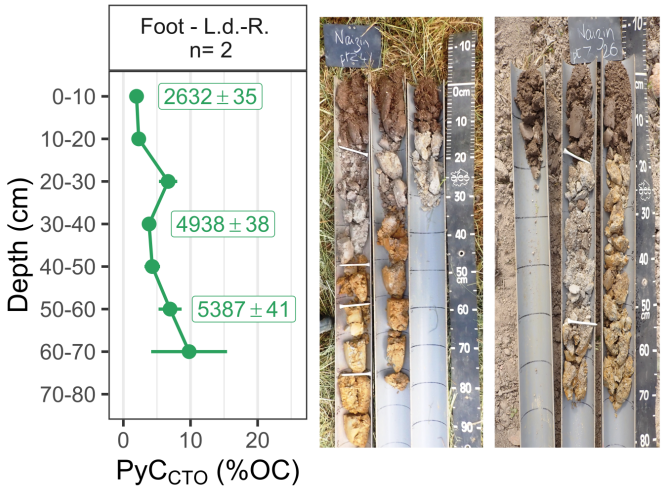


Relative to bulk SOC, soil PyC is **preferentially transported or preserved** at depth, independent of slope position

PyC fraction with depth for 6 representative combinations of soil type and slope position. Error bars represent the 95% confidence interval. Boxes indicate ^{14}C uncalibrated Before Present (BP) ages of the PyC_{HyPy} fraction ± 1 sd.
n number of sites, B. Brunisol, N. Neoluvisol, L. Luvisol, d. dégradé, -R. -Redoxisol

Rather preserved than transported because:
1) 2000 year age difference between surface and 55 cm depth (i.e no fast transport of “young” PyC)

Results and discussion: PyC vs. bulk SOC



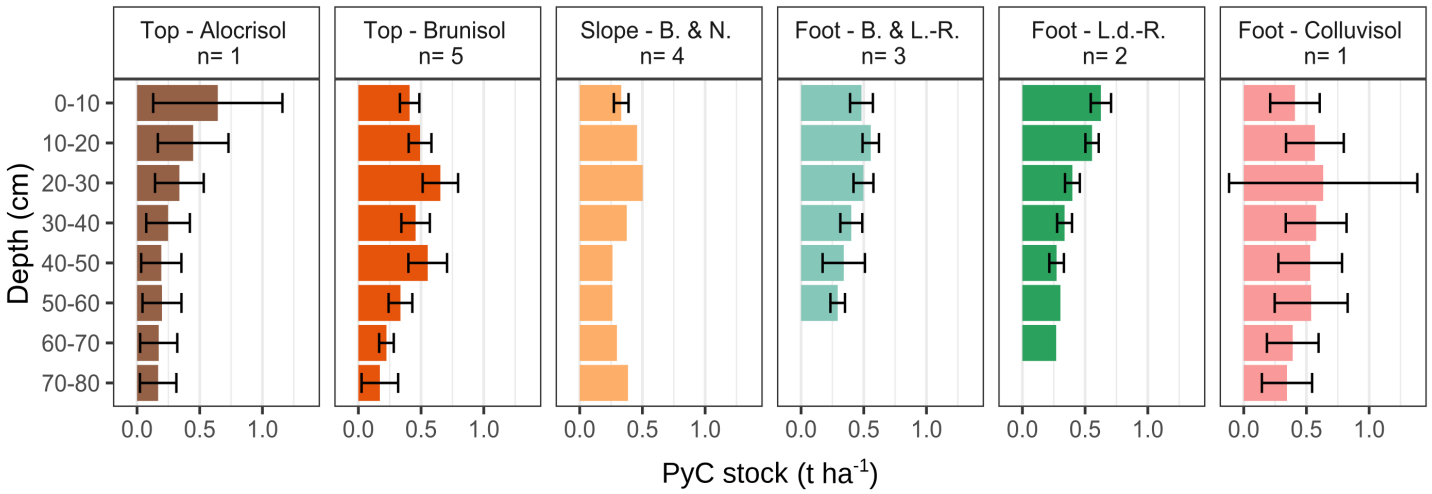
Relative to bulk SOC, soil PyC is **preferentially transported or preserved** at depth, independent of slope position

PyC fraction with depth for the 2 foot-hill sites where hydromorphy is the most marked. Error bars represent the 95% confidence interval. Boxes indicate ^{14}C uncalibrated Before Present (BP) ages of the PyC_{HyPy} fraction ± 1 sd. n number of sites, L. Luvisol, d. dégradé, -R. -Redoxisol Picture of the corresponding soil cores (courtesy of Christian Walter).

Rather preserved than transported because:

1) 2000 year age difference between surface and 55 cm depth (i.e no fast transport of “young” PyC)
2) Where elluviation processes have transported OC down the soil profile (Luvisol degradé – Redoxisol), PyC hasn’t been affected to the same extent as bulk SOC (notice the higher percentage of PyC to OC at 20-30 cm, where the grey/white elluviated horizon is present)

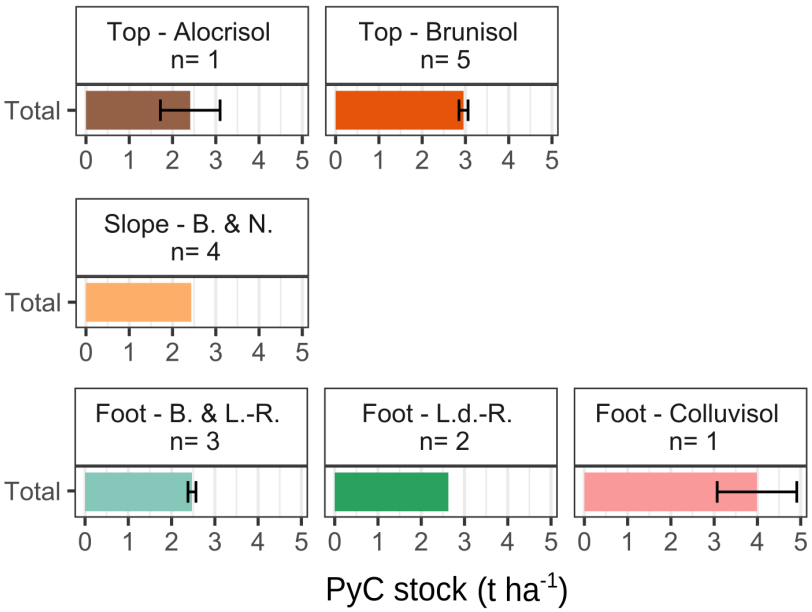
Results & discussion: PyC stock - profiles



PyC stocks below 30 cm represent **a third** of the total PyC stocks. This proportion is higher than for bulk SOC.

PyC stocks with depth for 6 representative combinations of soil type and slope position. Error bars represent the 95% confidence interval.
n number of sites, B. Brunisol, N. Neoluvisol, L. Luvisol, d. dégradé, -R. -Redoxisol

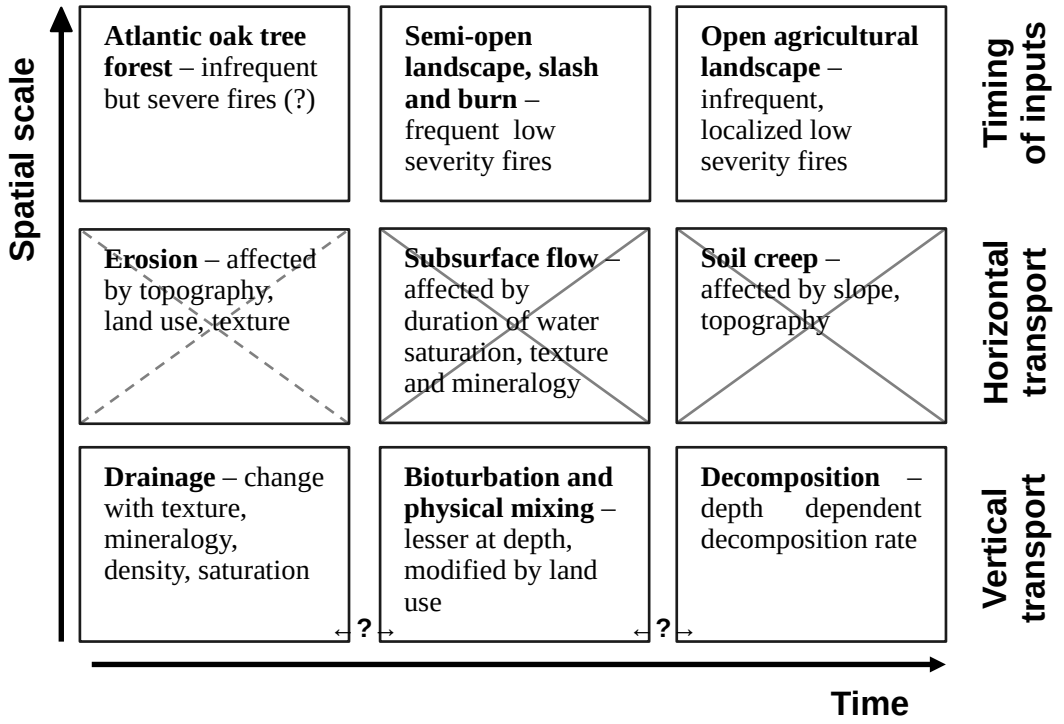
Results & discussion: PyC stock and slope position



- PyC stocks **do not depend on slope position** overall
- PyC stocks are higher where **erosion products accumulate** (Colluvisol)
- PyC stocks are higher in Brunisols at the top of the hill : why ?

Legend of the figure: Total PyC stocks for 6 representative combinations of soil type and slope position. Error bars represent the 95% confidence interval.
n number of sites, B. Brunisol, N. Neoluvisol, L. Luvisol, d. dégradé, -R. -Redoxisol

Discussion: drivers of PyC distribution



Follow up: test the effect of the timing of inputs, vertical transport and decomposition using a **1D carbon transport and decomposition model**.

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What can explain the observed profiles ?
PyC comes mostly from the surface. It then has to be transported downward into the soil profile.

Timing of inputs – land-use change (landscape scale)
Could the timing of input explain the stock profile? Effect of land-use change on the fire regime → frequency of fires (how are inputs distributed over time?) and intensity (how persistent is the deposited PyC?)

Horizontal transport (slope/watershed scale)
In this watershed horizontal transport has been excluded, except for the erosion-deposition mechanism in one case. Not unexpected since slopes < 5%

Vertical transport → see next slide

Discussion: drivers of PyC distribution

Presentation of the figure on-site. The little drawings can be lifted to allow the viewer to read the text.

Vertical transport (individual soil profile/soil type scale)
What could be the main transport mechanism:

- transport of dissolved and colloïdal PyC over time in drainage water,
- transport of PyC along with the mineral soil due to bioturbation or physical mixing (cryoturbation at the offset of the last glacial, eventually drying-rewetting/dessication cracks effect (in a silty textured soil?).

How fast is PyC decomposed in the course of transport?

Can the difference between OC and PyC profiles be explained by decomposition only or do we have to include transport? → I will explore this question using a 1D C transport and decomposition model fitted to the SOC, PyC and $^{14}C_{PyC}$ data

Acknowledgments

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NEIF

Field site and sampling

SAS

L'INSTITUT agro Rennes Angers

INRAE

OZCAR

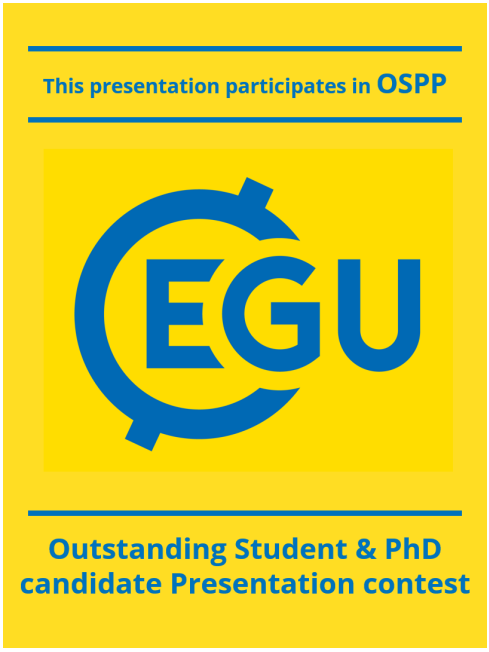
Soil physico-chemical properties

Laboratoire d'Analyses des Sols d'Arras

INRAE

ISTeP Institut des Sciences de la Terre de Paris
UMR 7193 - SU - CNRS

Going further



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