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International Union of Soil Sciences



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[www.centennialius2024.org](http://www.centennialius2024.org)

A-F. Didelot, A. Jaffrezic, T. Morvan, M. Liotaud, F. Gaillard, E. Jardé

**Does the chemical composition of organic waste products applied on soil impact the dissolved organic carbon concentration along the soil profile ?**

# Context and issues

Agronomic levers to improve soil health

Dissolved organic matter (DOM): labile and bioavailable fraction,  
energy source for microbial communities



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Application of farming **organic waste products (OWP)**

- Anaerobic digestion, different composition of **digestate** compared to initial OWP :  
enrichment in **recalcitrant molecules** (e.g. **lignin-derived**) (Häfner et al., 2022; Tambone et al., 2009) and **dicarboxylic acids** from acidogenesis stage (Liebetrau et al., 2017)
- DOM from **digestate** persists for longer in the soil ?
- **Auxin-like effect of digestate** (Ertani et al., 2013; Scaglia et al., 2015; 2017)

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- **Auxin-like effect of digestate** (Ertani et al., 2013; Scaglia et al., 2015; 2017)

Sowing of winter cover crops



- DOM from degradation of residues (roots, leaves, stems) and root exudation (Kalbitz et al., 2000)
- **Exudation**: low molecular weight compounds (e.g. dicarboxylic acids, carbohydrates) (Vives-Peris et al., 2019)

Enhancement of root biomass and exudation ?

# Context and issues

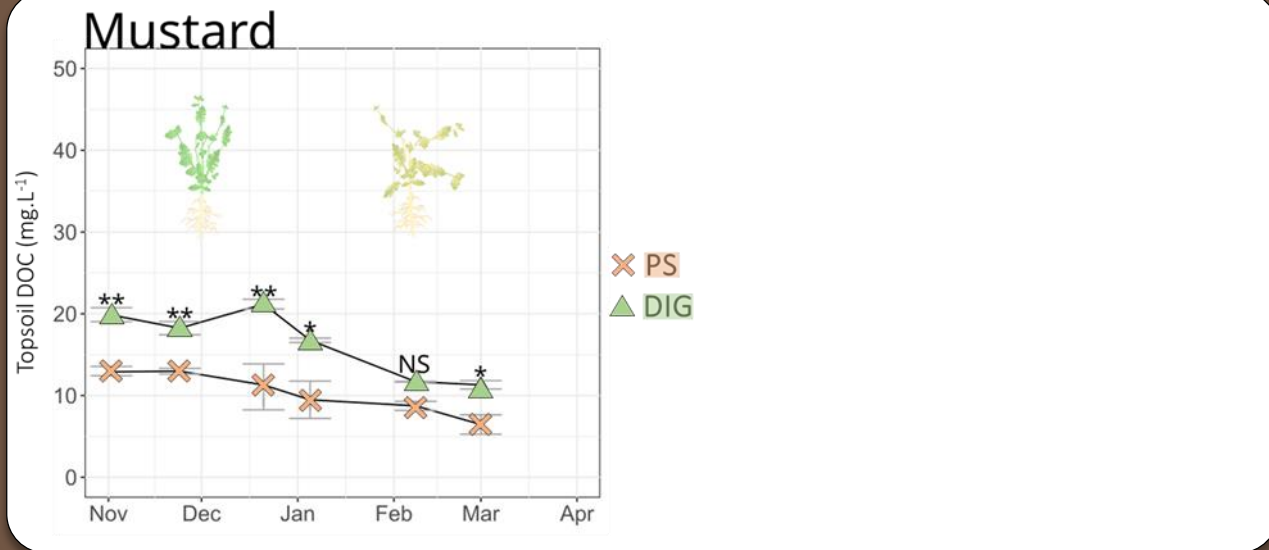
In a previous lysimeter study over 9 drainage seasons (Didelot et al., 2024 submitted) :  
Impact of **digestate (DIG)** and its original **pig slurry (PS)** on [dissolved organic carbon] (DOC)



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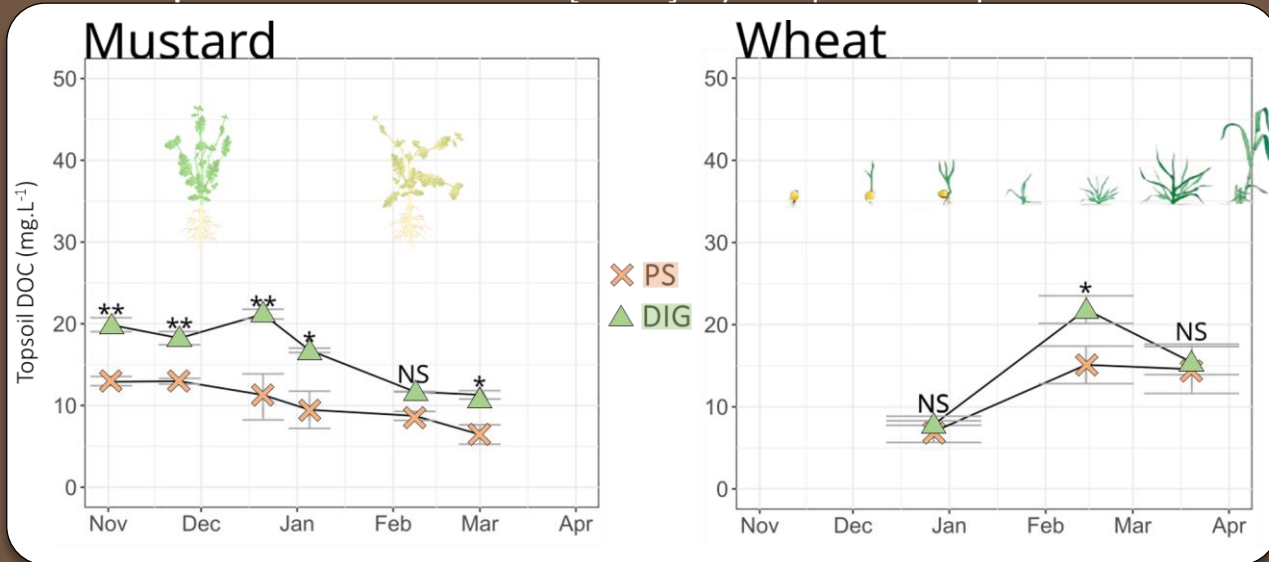
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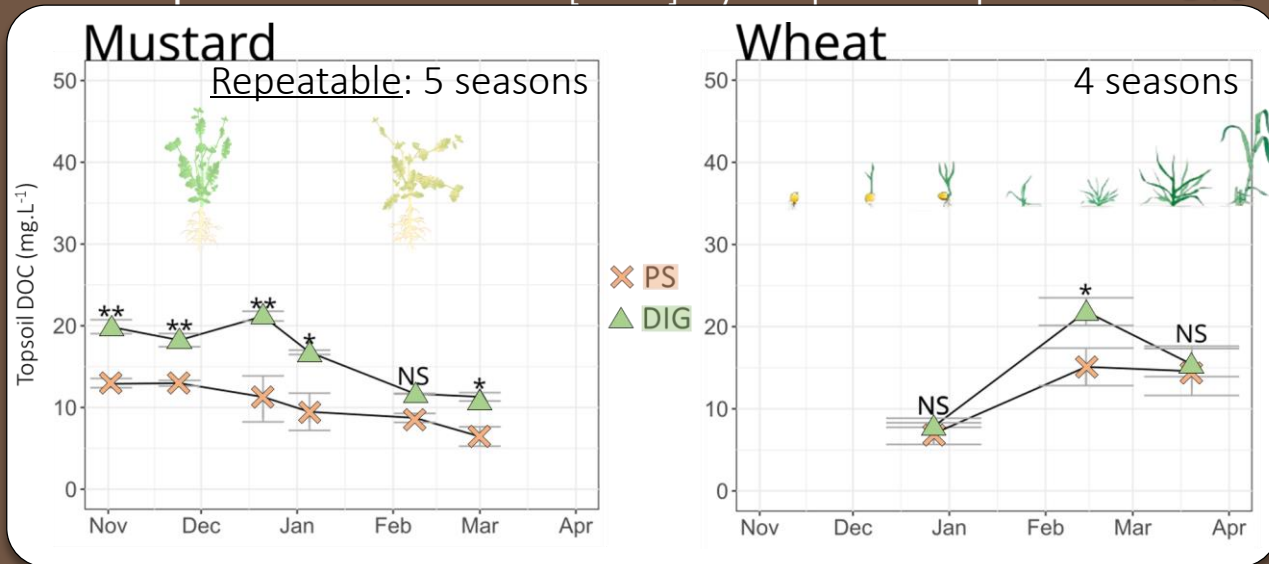
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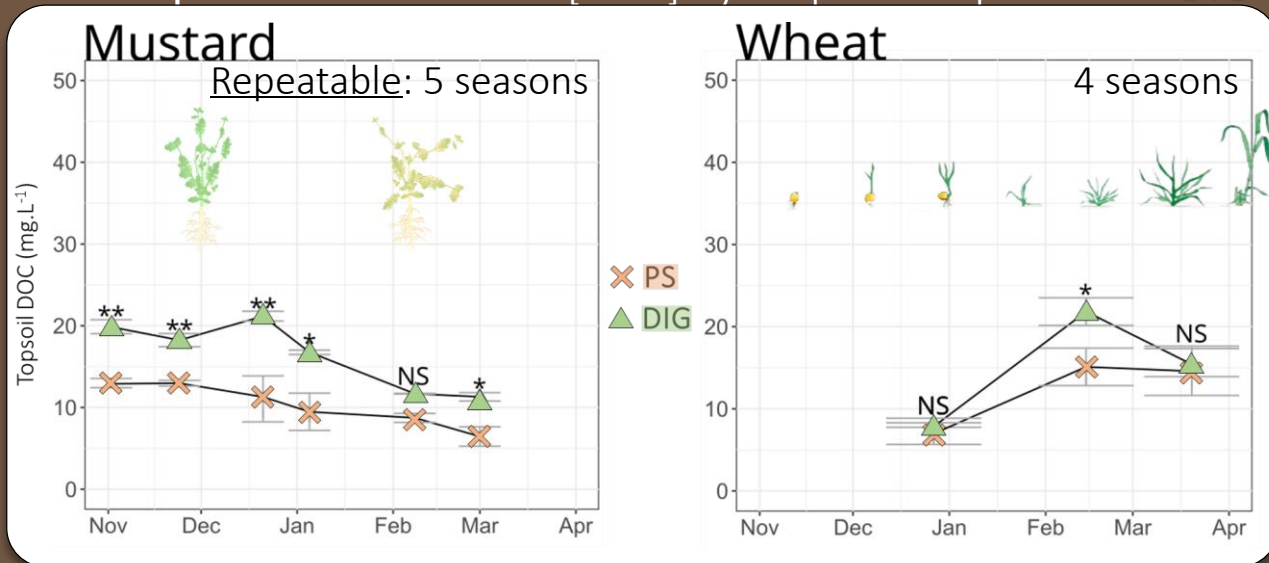




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Hypotheses :

Extra DOC ?



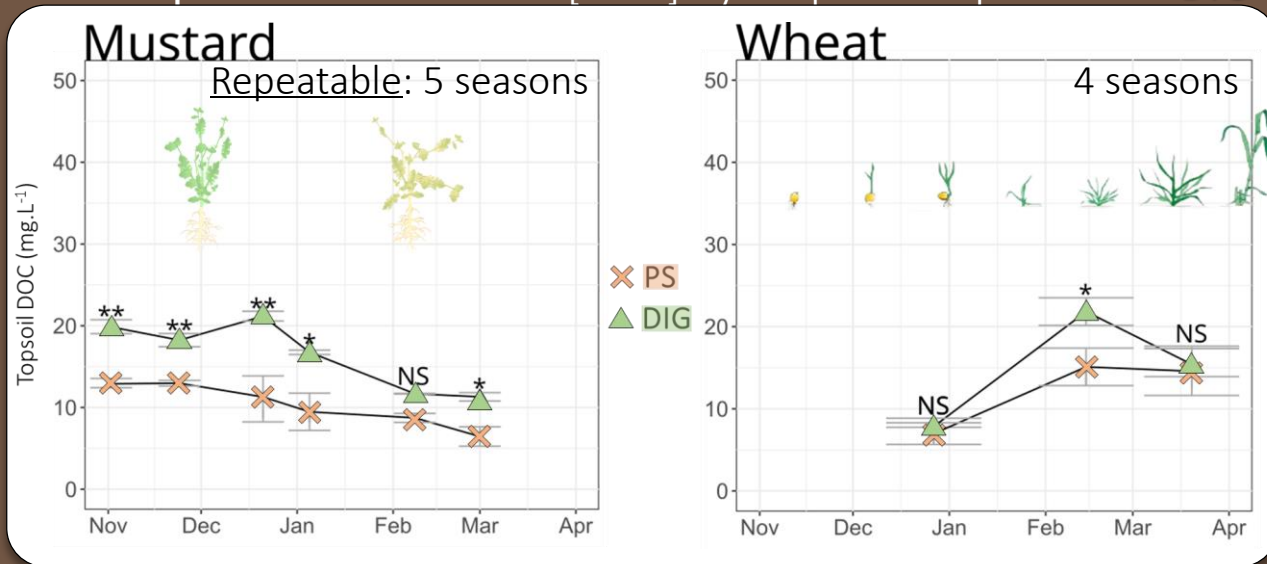
Solubilization of sorbed recalcitrant OM from DIG

Higher exudation through a potential auxin-like effect of DIG

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Higher exudation through a potential auxin-like effect of DIG

- Subsoil: no [DOC] difference between treatments

Hypothesis :

Preferential sorption on the mineral phase of the molecules transferred under the DIG modality

# Objectives

Differences in topsoil-[DOC] linked to differences in DOM composition ?  
Composition of DOM transferred to the subsoil ?



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- between different winter crops
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DOM composition analysed by thermochemolysis coupled to gas chromatography and mass spectrometry (THM-GC-MS) :  
identification of biomarkers that can bring information regarding the DOM sources

# Material and methods

Study site: EFELE (SOERE PRO network)

- Long-term observatory (2012-2032) in Northwest France
  - 2 treatments applied in spring :
    - Pig slurry (PS)
    - Digestate from this pig slurry (DIG)
- Equivalent N supply

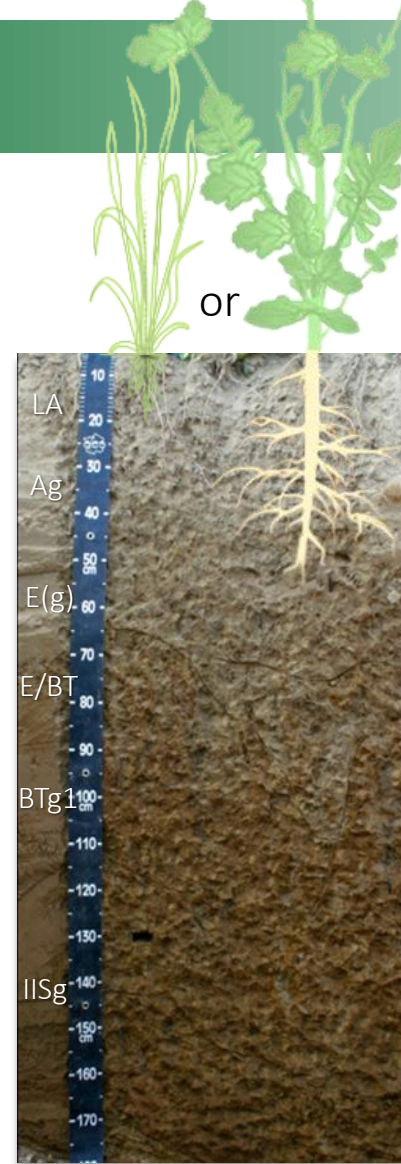


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Topsoil: 1.2%  $C_{orga}$ , pH 6.3  
Subsoil: 0.2%  $C_{orga}$

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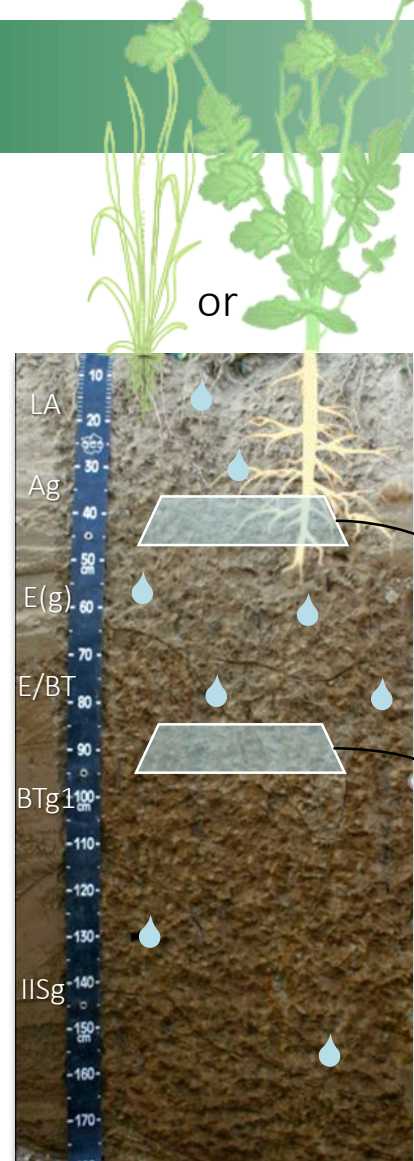


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 ] Equivalent N supply
- Winter crops: winter wheat (sown in November) or white mustard (sown in September)
- Soil solution : topsoil (40cm) and subsoil (90cm)



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**Drainage** season:  
 November to March

Sample collection,  
 filtration, [DOC]  
 measurement



# Material and methods

Selection of one season for each crop: representative of the other seasons (repeatable)

THM-GC-MS analyses on :

- Lysimeters samples: 2 dates/season in the topsoil + 1 date in the subsoil
- Water-extractable OM (WEOM) from the raw **PS** and **DIG**



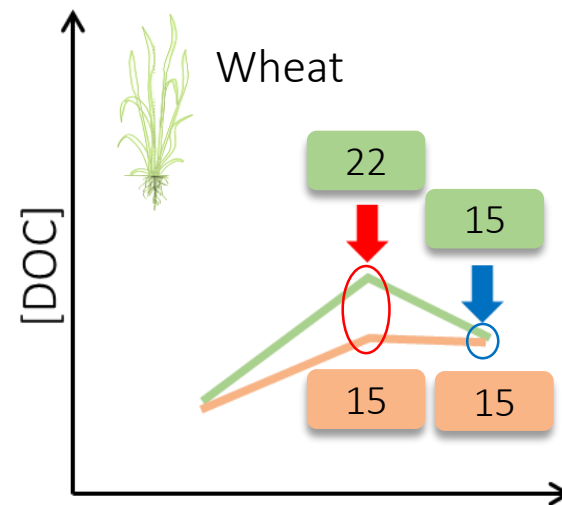
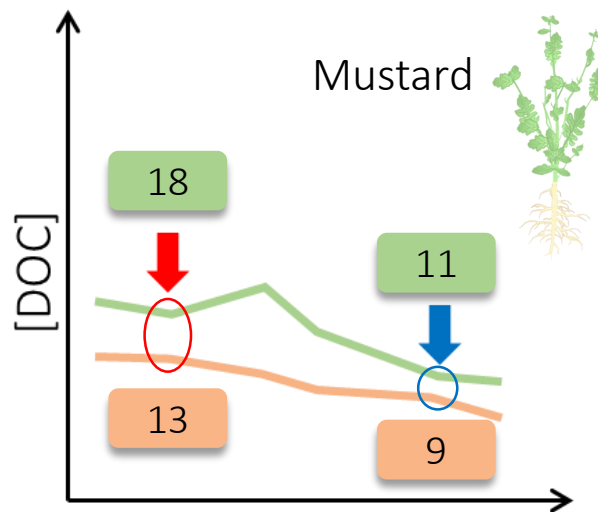
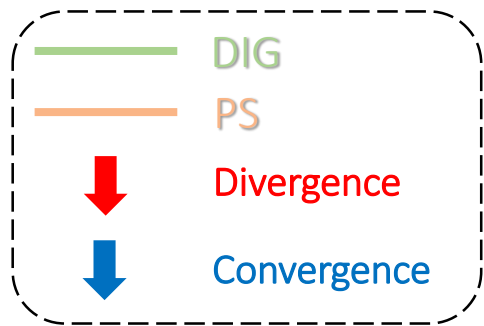
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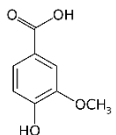
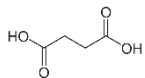
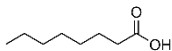
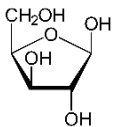
Topsoil [DOC] in mg.L<sup>-1</sup> :



Average subsoil [DOC]:  $0.9 \pm 0.2$  mg.L<sup>-1</sup>

# Material and methods

Identification by THM-GC-MS of 46 target molecules (4 groups)  
= biomarkers derived from plants or microorganisms



- Carbohydrates (CAR)

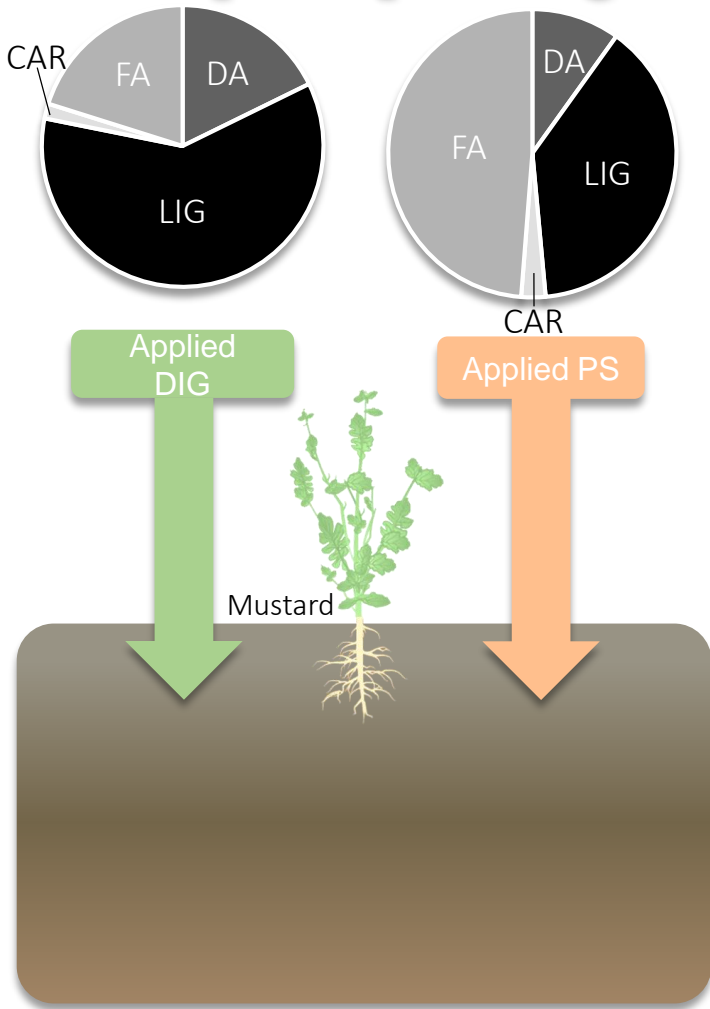
- Fatty acids (FA)

- Dicarboxylic acids (DA)

- Lignin and tannin derived markers (LIG)

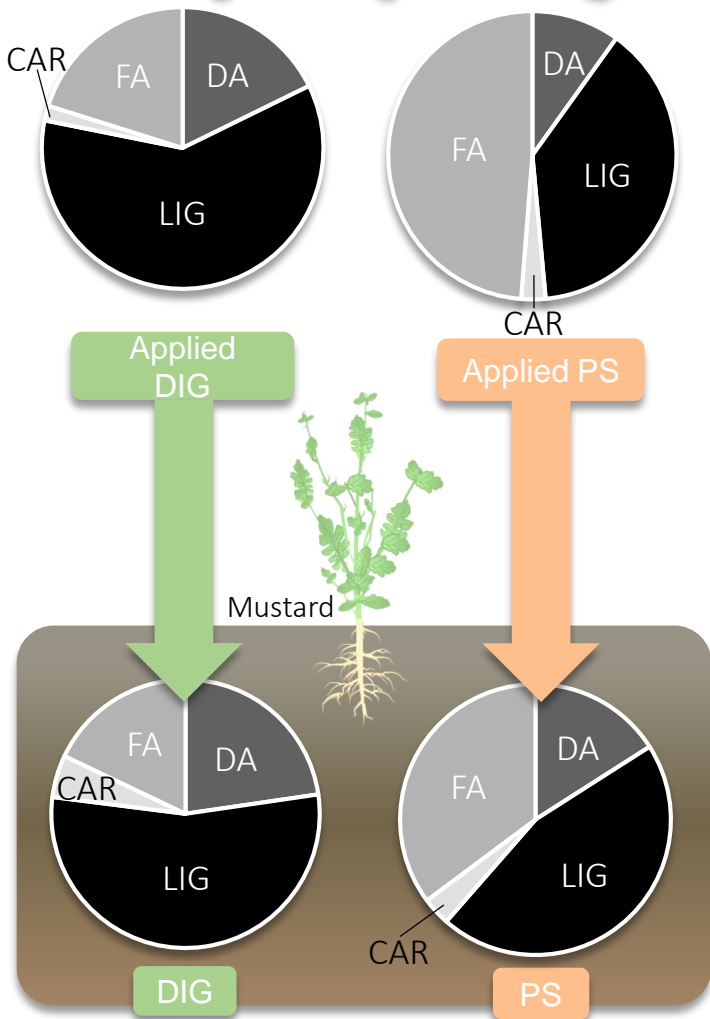


# Results and discussion – DOM composition under mustard when [DOC] diverged (November)



Applied DIG : high %LIG and %DA  
Applied PS : high %FA

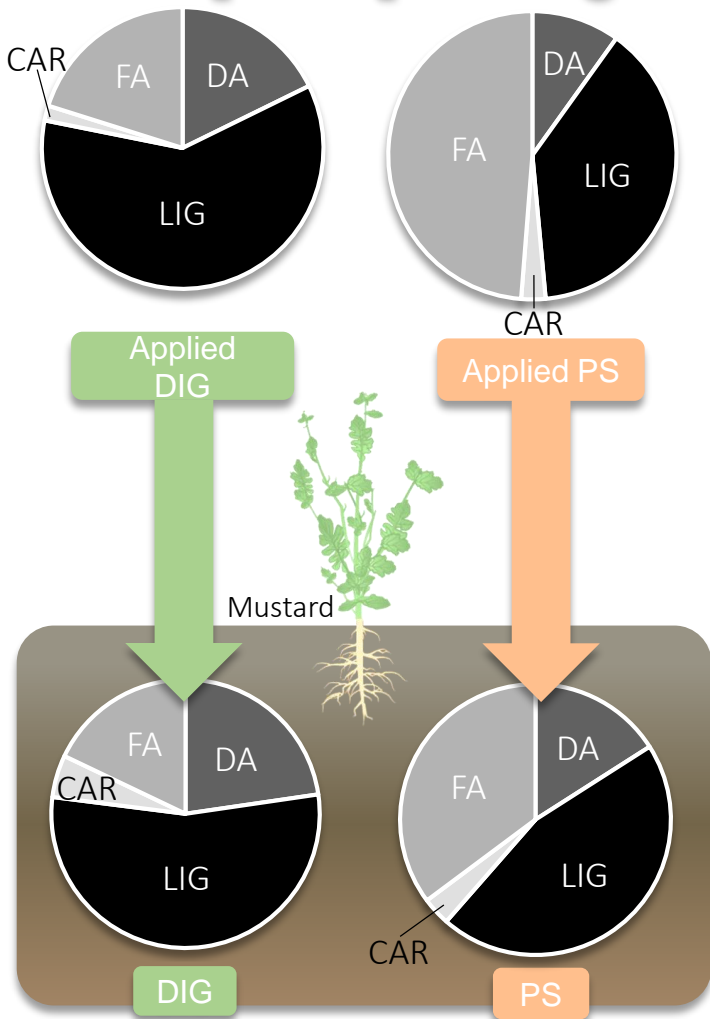
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**DIG contribution** 

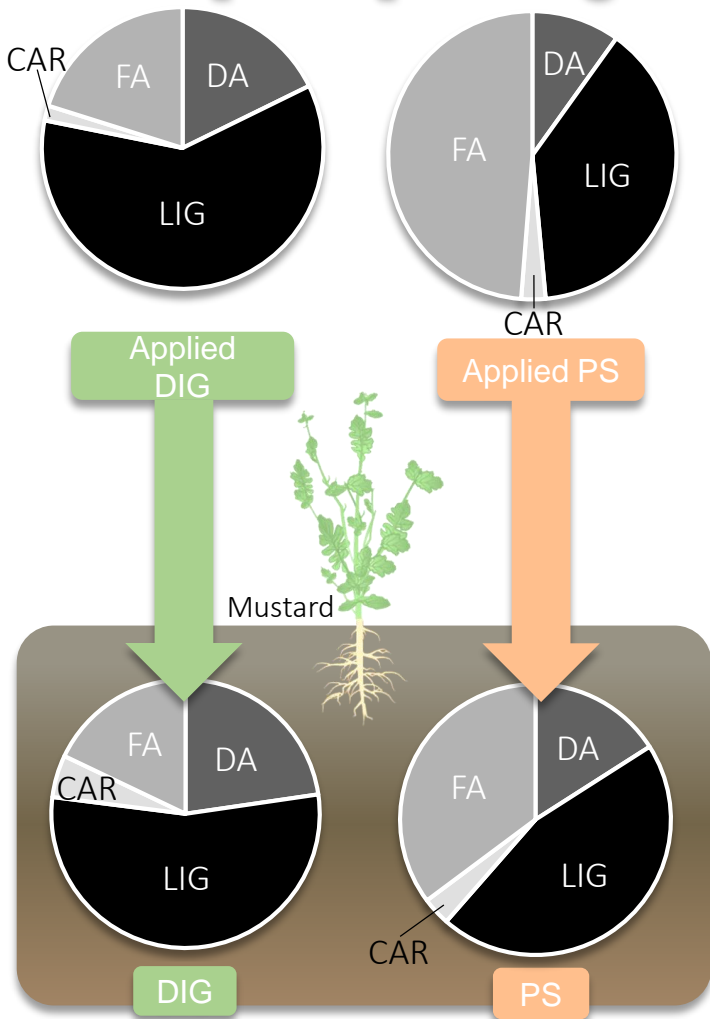
Recalcitrant OM from DIG sorbed on topsoil's minerals

Mustard = catch crop  
 Alkalinization of the rhizosphere by nitrates uptake  
 (Hinsinger et al., 2003)

↓

Desorption of DOM (Andersson et al., 2000) from DIG

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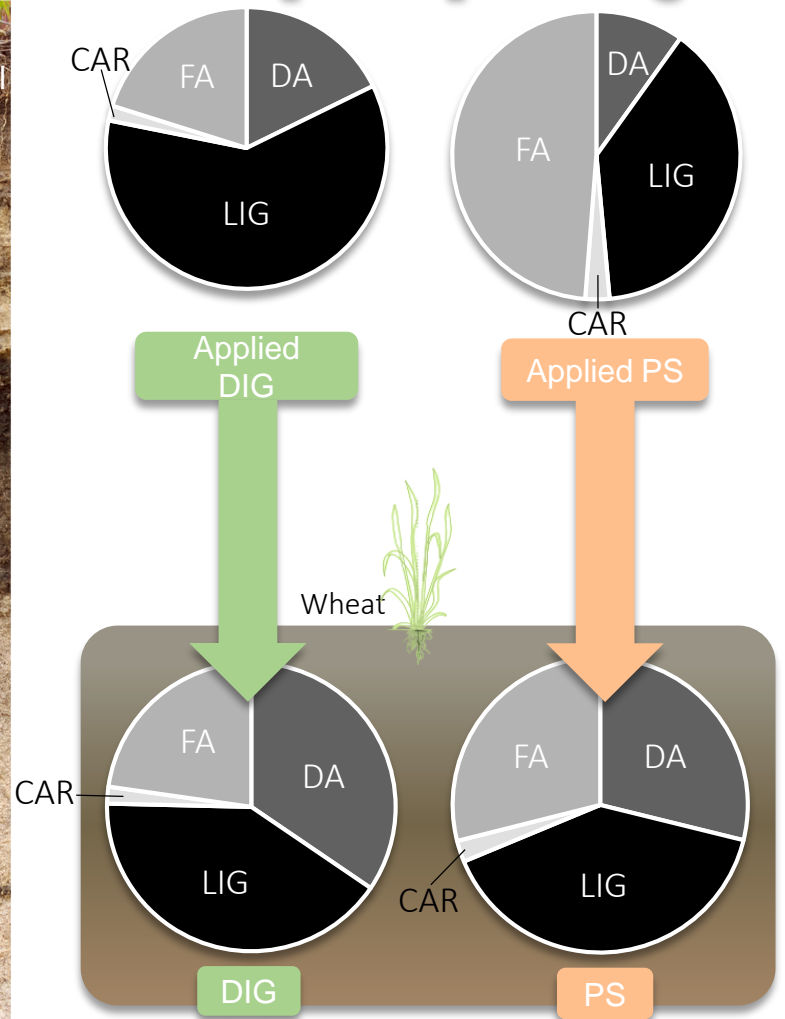
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**Crop contribution**

**Mustard** (sown in September): peak of DA exudation of Brassicaceae (Mimmo et al., 2011; Kim et al., 2010) around October  
Before the drainage season

Low contribution to DOM pool

# Results and discussion – DOM composition under wheat when [DOC] diverged (February)

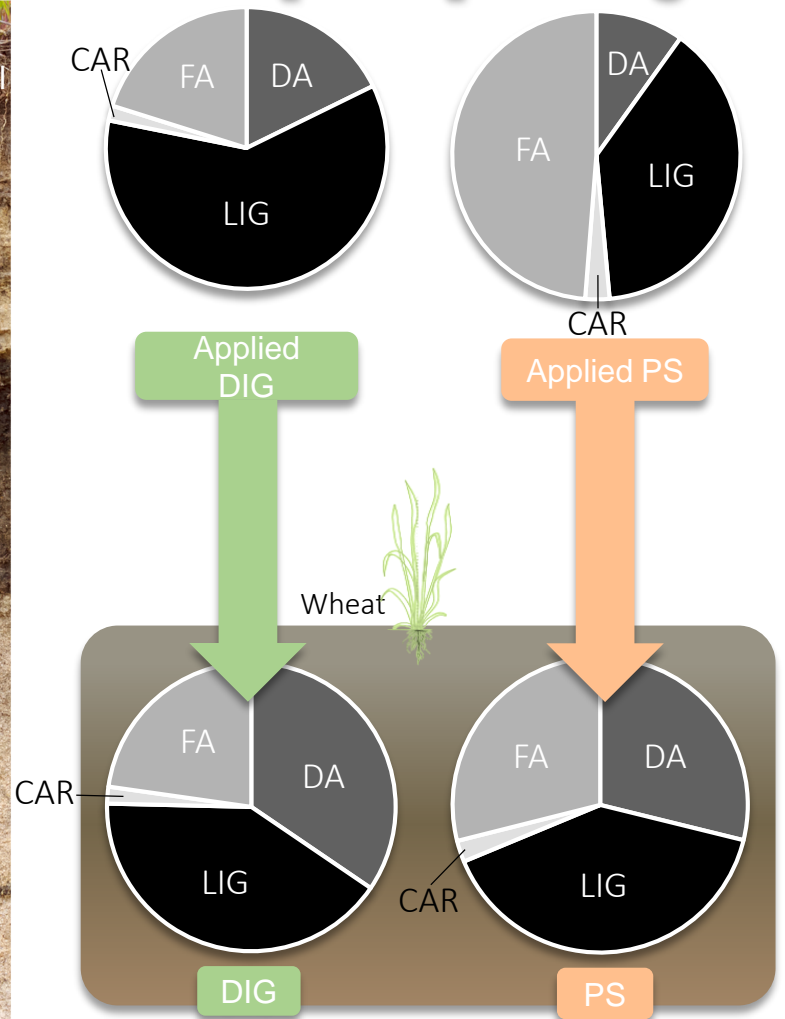


In soil solution :

- DIG : high %DA and %LIG, applied DIG signature less obvious
- PS : high %FA, %LIG, %DA

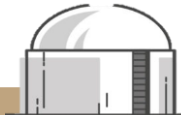


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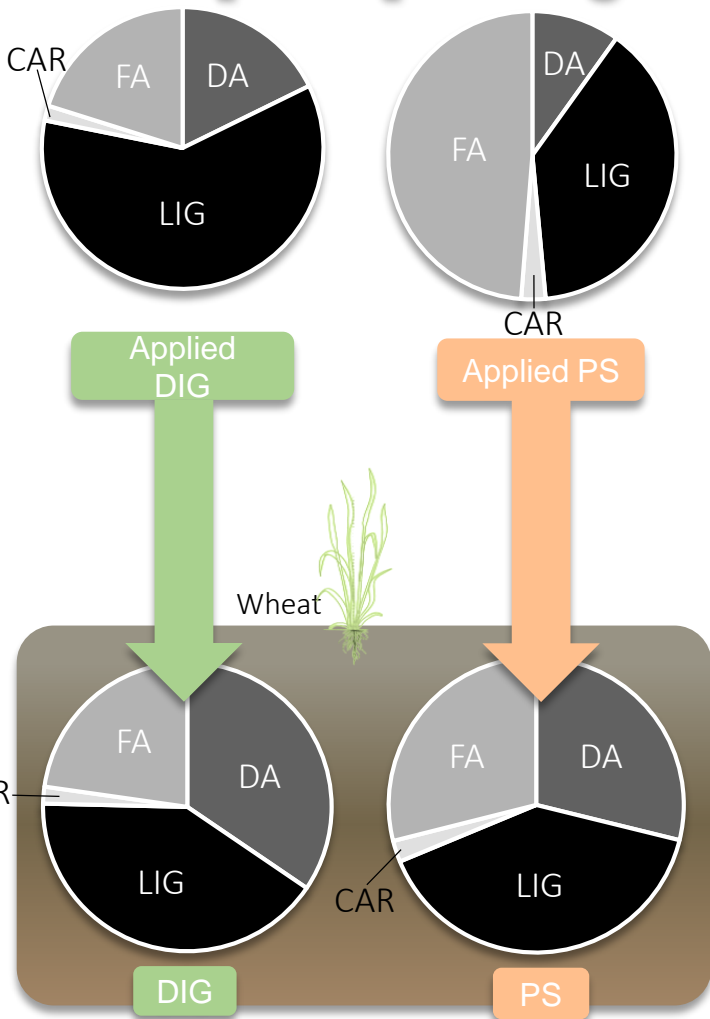
**DIG contribution** 

Slight alkalinization of the rhizosphere by nitrates uptake  
(Wheat = not a catch crop)

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Slight desorption of DOM from DIG

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Slight alkalization of the rhizosphere by nitrates uptake (Wheat = not a catch crop)

↓

Slight desorption of DOM from DIG

**Crop contribution**

Wheat (sown in November): jointing stage around February-March

↓

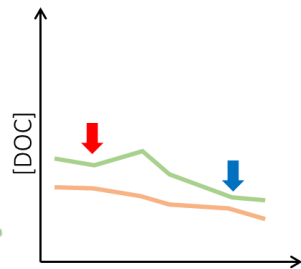
High exudation of DA to attract growth-promoting rhizobacteria (Chen et al., 2019)

↪ Enhanced by auxin-like effect ?

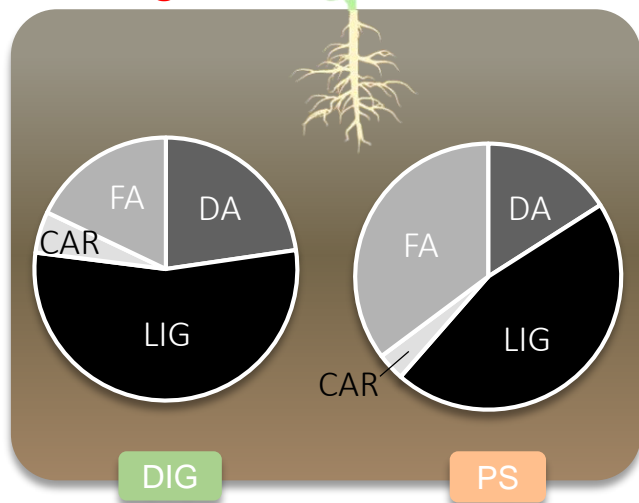
# Results and discussion – DOM composition evolution

(Example for mustard)

Topsoil



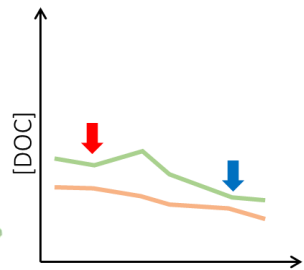
[DOC]  
divergence



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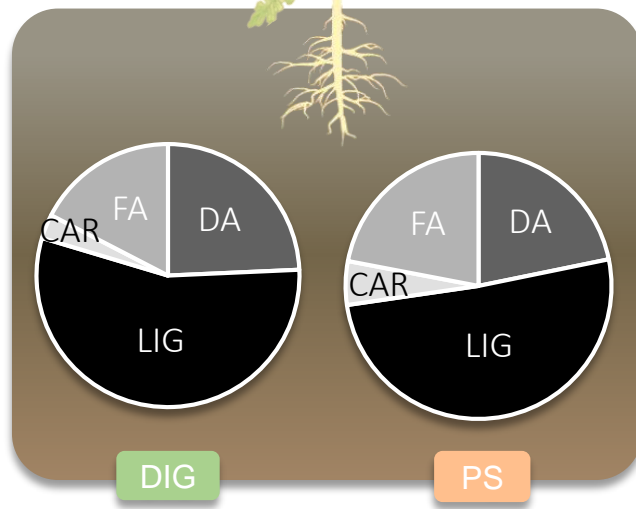
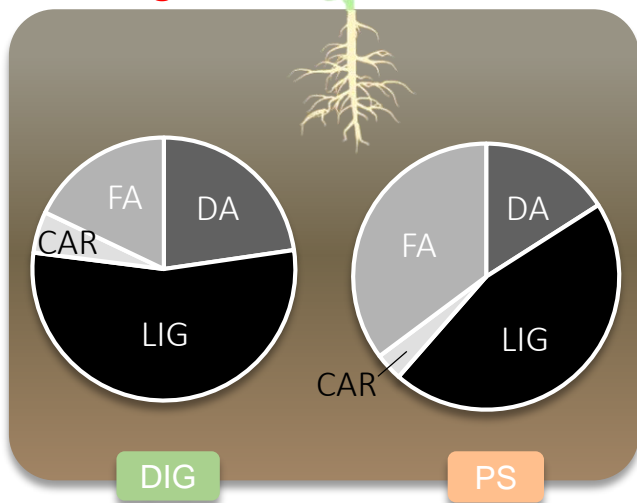
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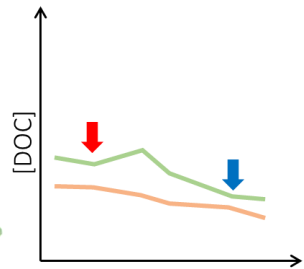
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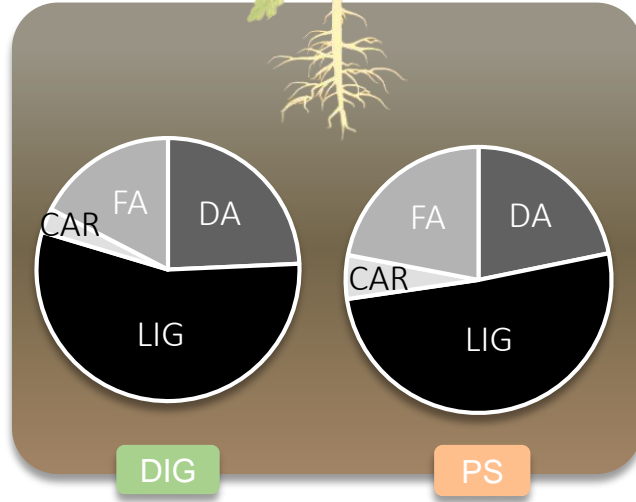
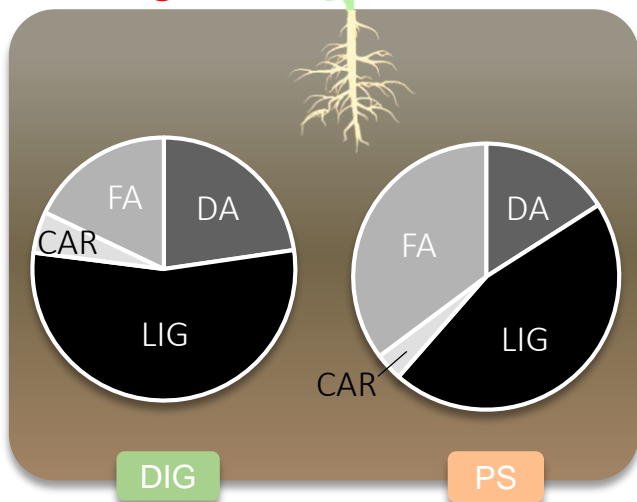


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[DOC] divergence

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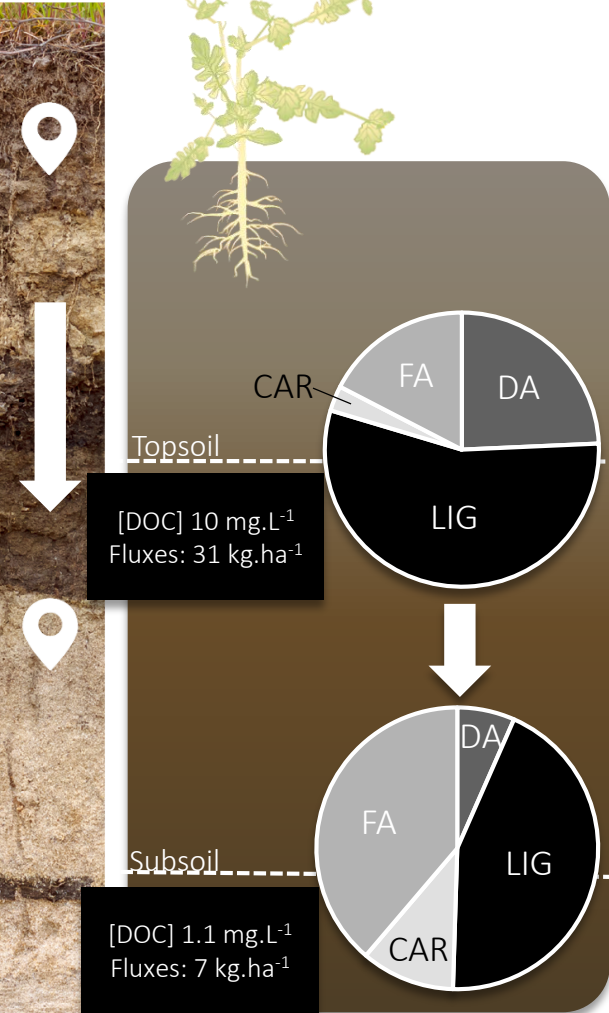


Toward the end of the drainage season :

- DIG : no evolution, lower quantity of DOC but constant DOM quality
- PS : overall decrease of %FA and increase of %DA



# Results and discussion – DOM transfer

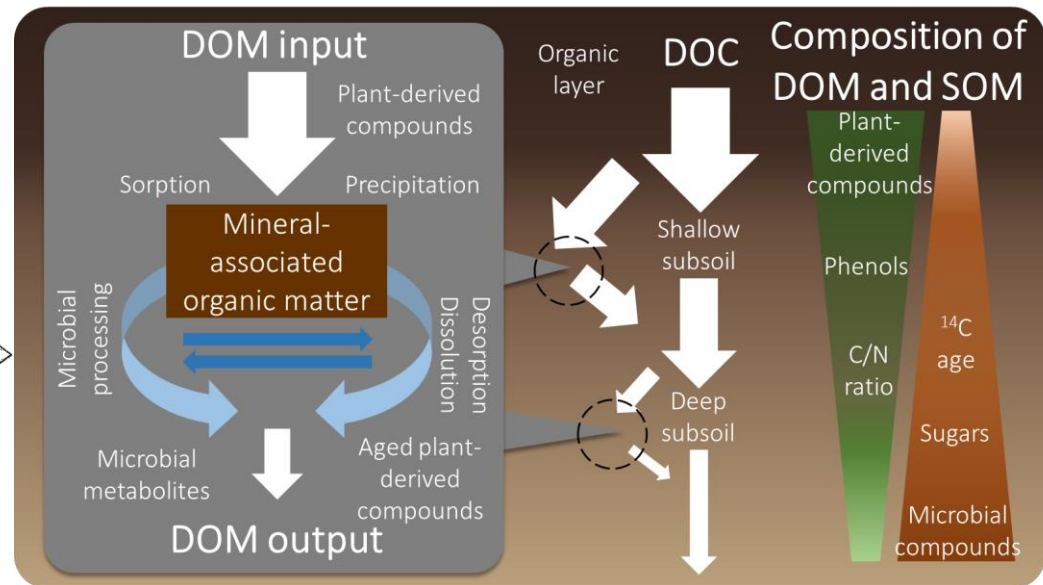


- Topsoil : higher %DA and %LIG
- Subsoil : higher %CAR and %FA

	% microbial-derived	% plant-derived
Topsoil	16 ± 2%	84 ± 2%
Subsoil	38 ± 4%	62 ± 4%

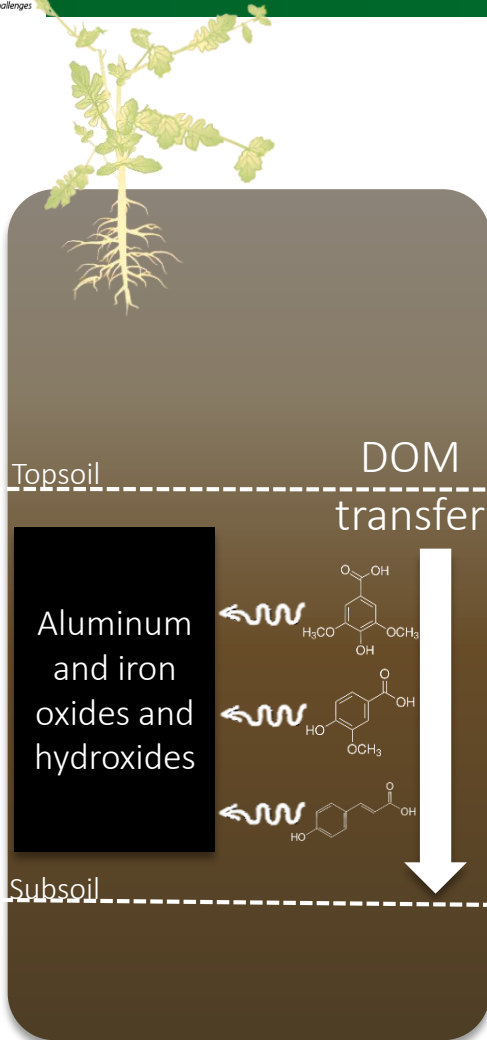
Decrease of plant-derived molecules and increase of microbial-derived molecules with depth

In accordance with the model from Kaiser and Kalbitz (2012)

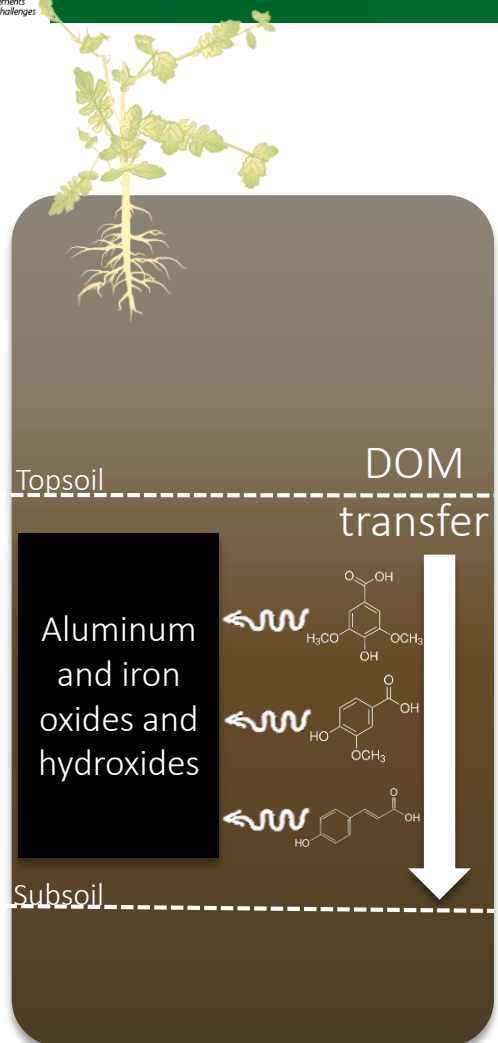


# Results and discussion – DOM transfer

Preferential sorption of acidic LIG  
(Kaiser et al., 2004)



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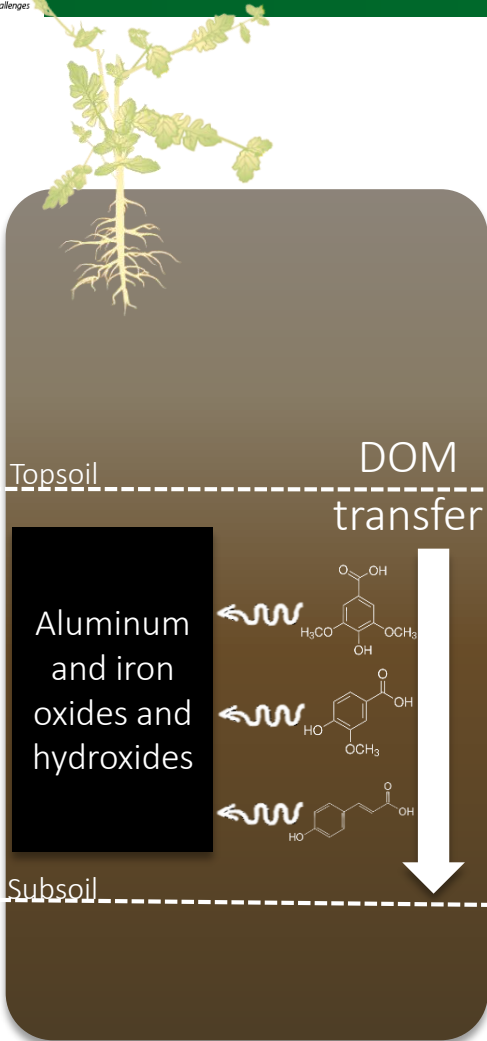
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Proportions of acidic LIG

	DIG	PS
Topsoil	32 ± 2%	24 ± 2%
Subsoil	9 ± 0.3%	7 ± 3%



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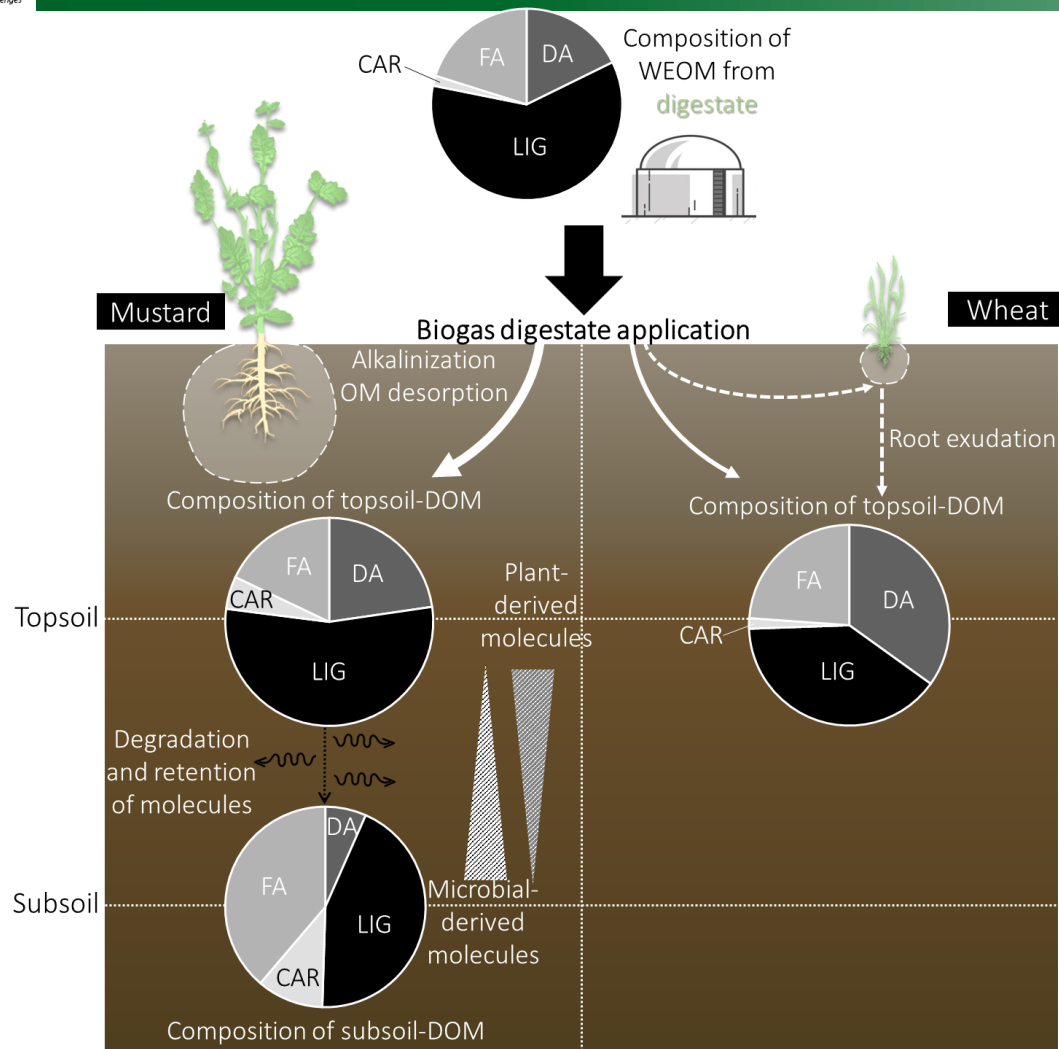
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Greater sorption of molecules for the DIG modality -> potentially higher C storage in the subsoil ?

# Conclusion



- Modulation of DOM quantity and quality by crop (soil alkalinization and desorption, exudation)
- Main source of DOM under mustard: recalcitrant molecules from **digestate**
- Main sources of DOM under wheat: molecules from **digestate** and root exudation
- Decrease of plant-derived molecules and increase of microbial-derived molecules with depth
- High sorption of molecules between the topsoil and subsoil for the **digestate** modality

Thanks for your attention