EGU General Assembly 2020

Contribution of inorganic carbon to CO_2 emissions under a Mediterranean agroforestry system

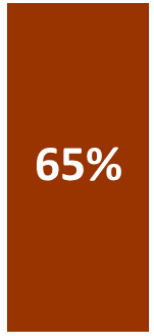
Tiphaine Chevallier, Rémi Cardinael, Bertrand Guenet, Thomas Cozzi, Cyril Girardin, Claire Chenu

Soil Carbon

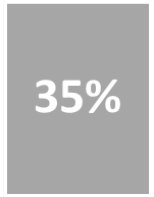
Soil Organic Carbon (SOC)

SOC are
- all the form of organic matter
- Fine, coarse
- Labile, resistant
- Solid, in solution

0-30 cm



1583 Gt SOC



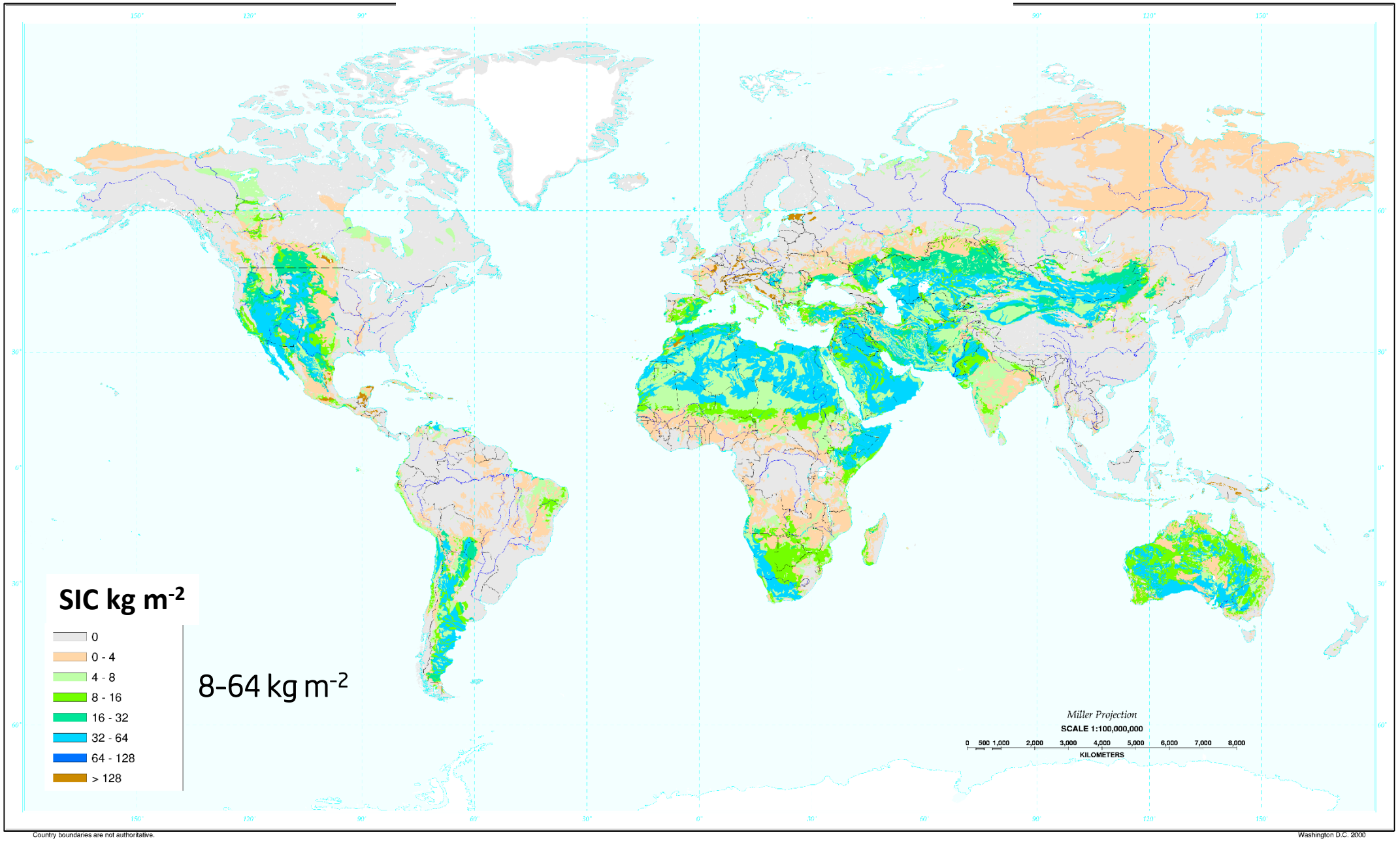
946 Gt SIC

and

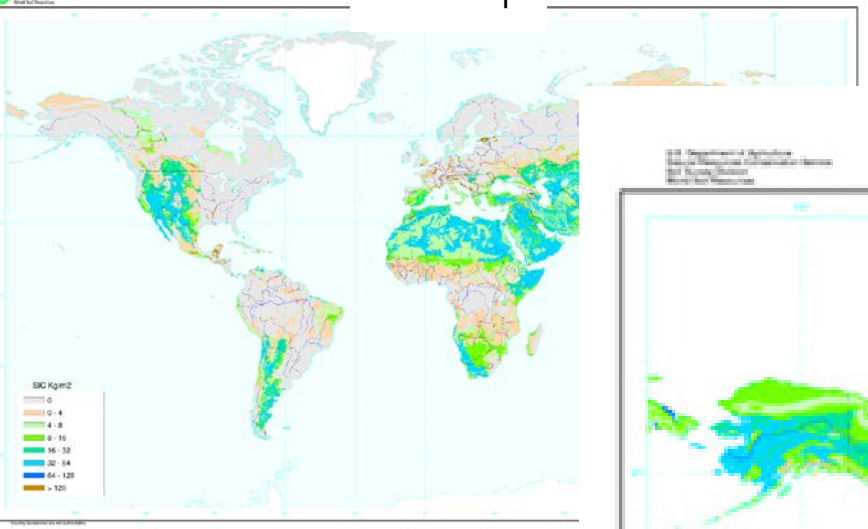
Soil Inorganic Carbon (SIC)

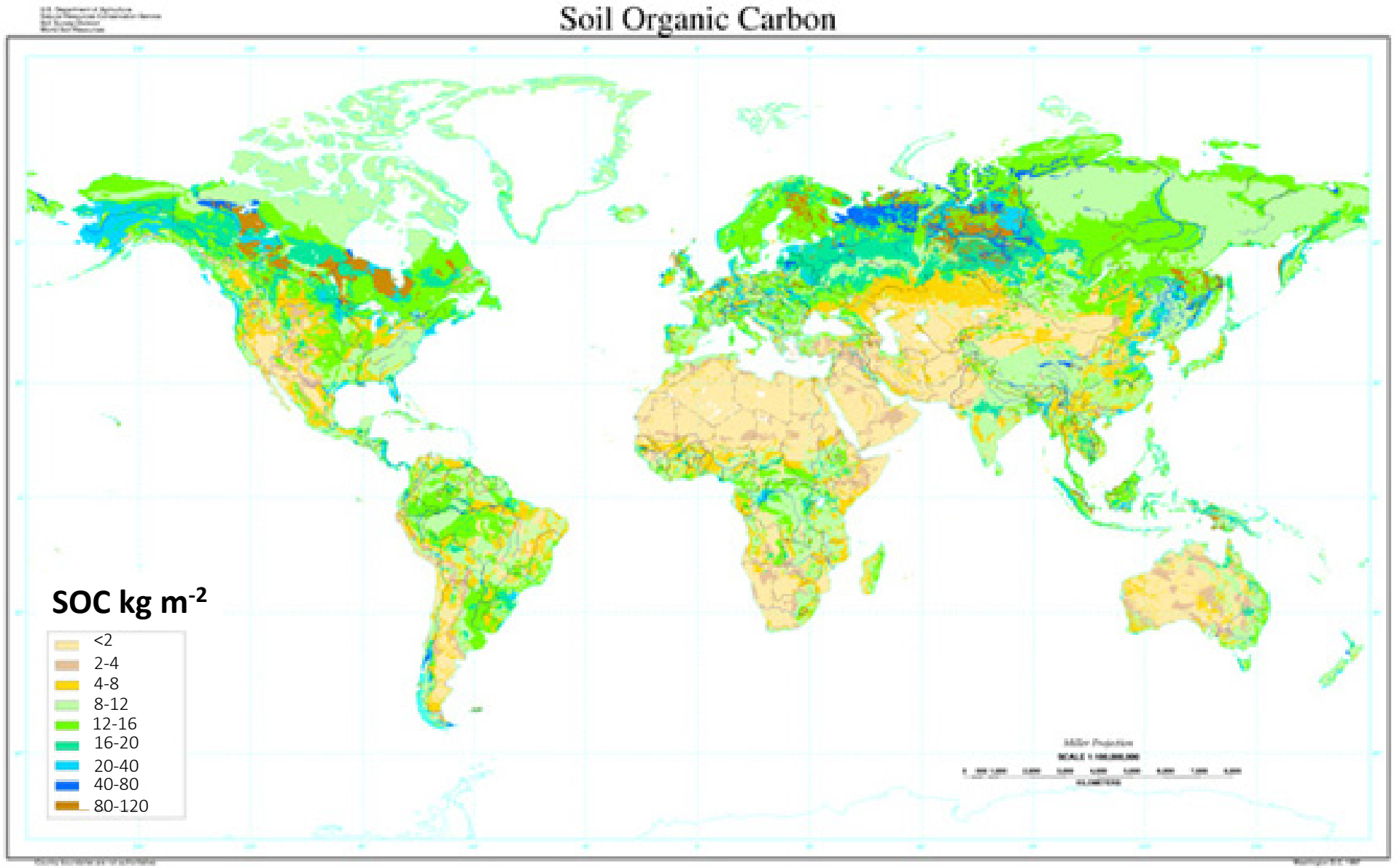
SIC are
- $CaCO_3$ and others ($CaMg(CO_3)_2$...)
- HCO_3^-
- H_2CO_3
- CO_2
- Solid, in solution, gaz

Soil Inorganic Carbon map



SIC map





Source : FAO-UNESCO, Soil Map of the World, digitized by ESRI. Soil climate map, USDA-NRCS, Soil Science Division, World Soil Resources, Washington D.C. Soil Pedon database, USDA-NRCS National Soil Survey Center, Lincoln, NE.

Soil Carbon

Soil Organic Carbon (SOC)

Unlocking the potential of mitigating and adapting to a changing climate

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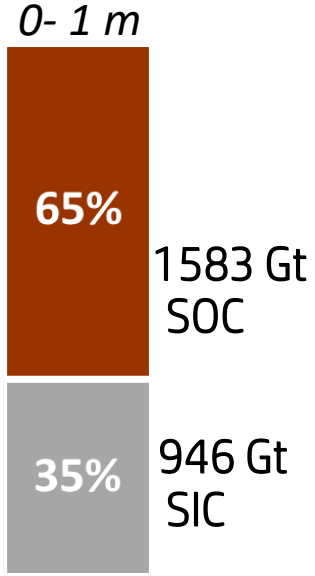


and

Soil Inorganic Carbon (SIC)

Does SIC impact global C at short scales ? Does SIC impact SOC cycle ?

SIC are
- $CaCO_3$
- HCO_3^-
- H_2CO_3
- CO_2
- Solid, in solution, gaz

Calcareous soils are poorly studied

Methodological issues to separate SOC and SIC dynamics

- *Analyzing SOC and SIC in calcareous soils*

Promising Mid-infrared spectrometry analysis
See Chevallier et al. (poster in the EGU section)
Prediction of SOC and SIC concentrations in Tunisian samples by mid-infrared reflectance spectroscopy using a French national library

- *Dynamics of C contents and stocks*

At short incubation time (days, months), does the CO_2 emitted come only from SOC decomposition ?

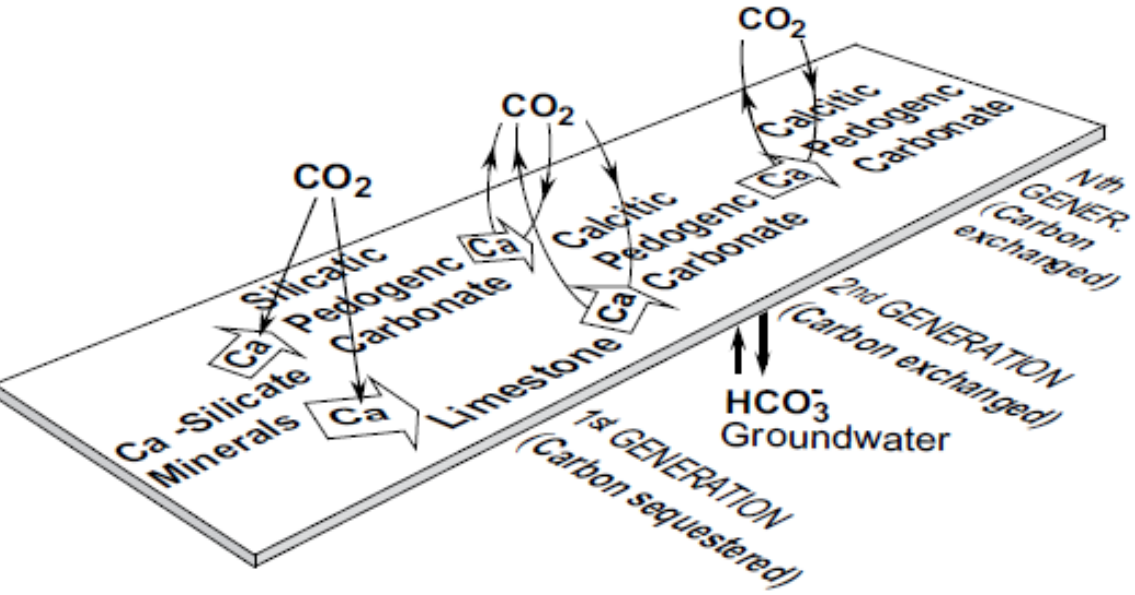
SOC and SIC interact via biological activities

SIC are
- $CaCO_3$
- HCO_3^-
- H_2CO_3
- CO_2
- Solid, in solution, gaz

$$CaCO_3 + 2H^+ \rightleftharpoons Ca^{2+} + CO_2 + H_2O$$

$$CaCO_3 + H_2O + CO_2 \rightleftharpoons Ca^{2+} + 2\,HCO_3^-$$

Solid-solution-gaz equilibirum = f(pH, H_2o, pCO_2, Ca^{2+}, HCO_3^-)



Monger et al. 15, Geology

- SIC interacts with CO_2 driven by biotic activities
- SOC and SIC evolution are likely link

Is SIC pool important to consider in SOC studies in calcacerous soils ?

Methodological issues to separate SOC and SIC dynamics

- *Analyzing SOC and SIC in calcareous soils*

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- *Dynamics of C contents and stocks*

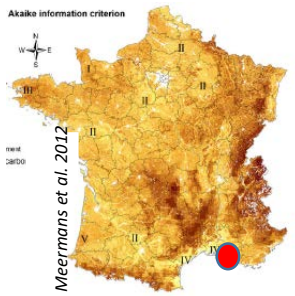
Does the CO_2 measured come only from SOC decomposition ?

If SIC contributes to CO_2 emissions, is this contribution homogeneous along the soil profile?

Does depth impact SOC and SIC dynamics in the same way?

Is there a correlation between SOC and SIC dynamics ?

Material and methods



Agroforestry system (Walnut trees with durum wheat crop)
Control plot (Durum wheat crop)

On Fluvisol, near Montpellier (south of France) described in Cardinael et al. 2015

SOC, SIC, C contents, and ^{13}C were measured

4 depths x 3 locations (tree row, alley, control plot) x 4 replicates = 48 soil samples

4 soil depths

Soil incubation for 44 days at 20°C

Kinetics of the amount of CO_2 emisssions and $^{13}CO_2$ emissions were measured

^{13}C-Carbon Isotopic measurements

To separate SOC from SIC, and

CO_2 coming from SOC ($SOC\text{-}CO_2$) isotopically different of CO_2 coming from SIC ($SIC\text{-}CO_2$)

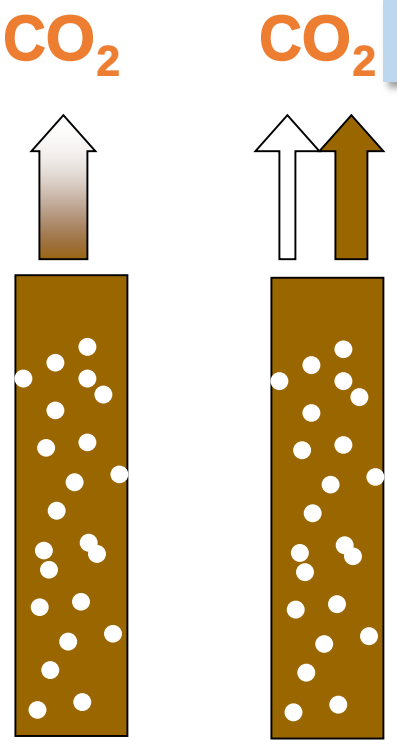
Carbon Isotopic measurements

$\delta^{13}C$ of SIC in a range +2 to -11 ‰

$\delta^{13}C$ of SOC about -25 to -27 ‰ (C3 plants)

$\delta^{13}C$ of soil in between

$$\delta^{13}C_{soil} = f\ \delta^{13}C\text{-}SIC + (1-f)\ \delta^{13}C\text{-}SOC$$



$$\delta^{13}C\text{-}CO_2 = f_{SIC}\ \delta^{13}C\text{-}SIC + (1-f_{SIC})\ \delta^{13}C\text{-}SOC$$

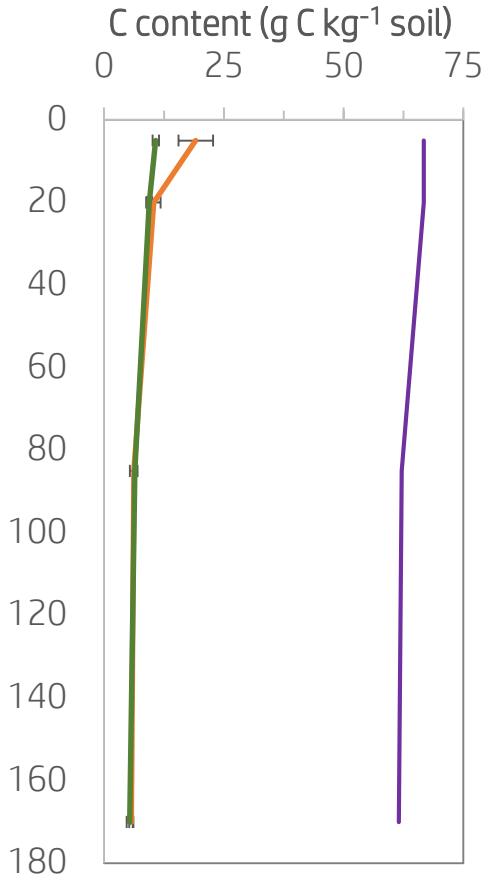
If no isotopic fractionations between

- SOC and CO_2 (biological activities)
- $CaCO_3$, HCO_3^-, CO_2

$$CO_2 = SIC\text{-}CO_2 + SOC\text{-}CO_2$$
$$SIC\text{-}CO_2 = f_{SIC} \times CO_2$$
$$SOC\text{-}CO_2 = (1-f_{SIC}) \times CO_2$$

Stevendon and Verburg, 06, Bertrand et al. 07, Rovira and Vallejo 08, Inglima et al. 09, Ramnarine et al. 12, Tamir et al. 11, 12, Ahmad et al. 14, Chevallier et al. 16…

Results



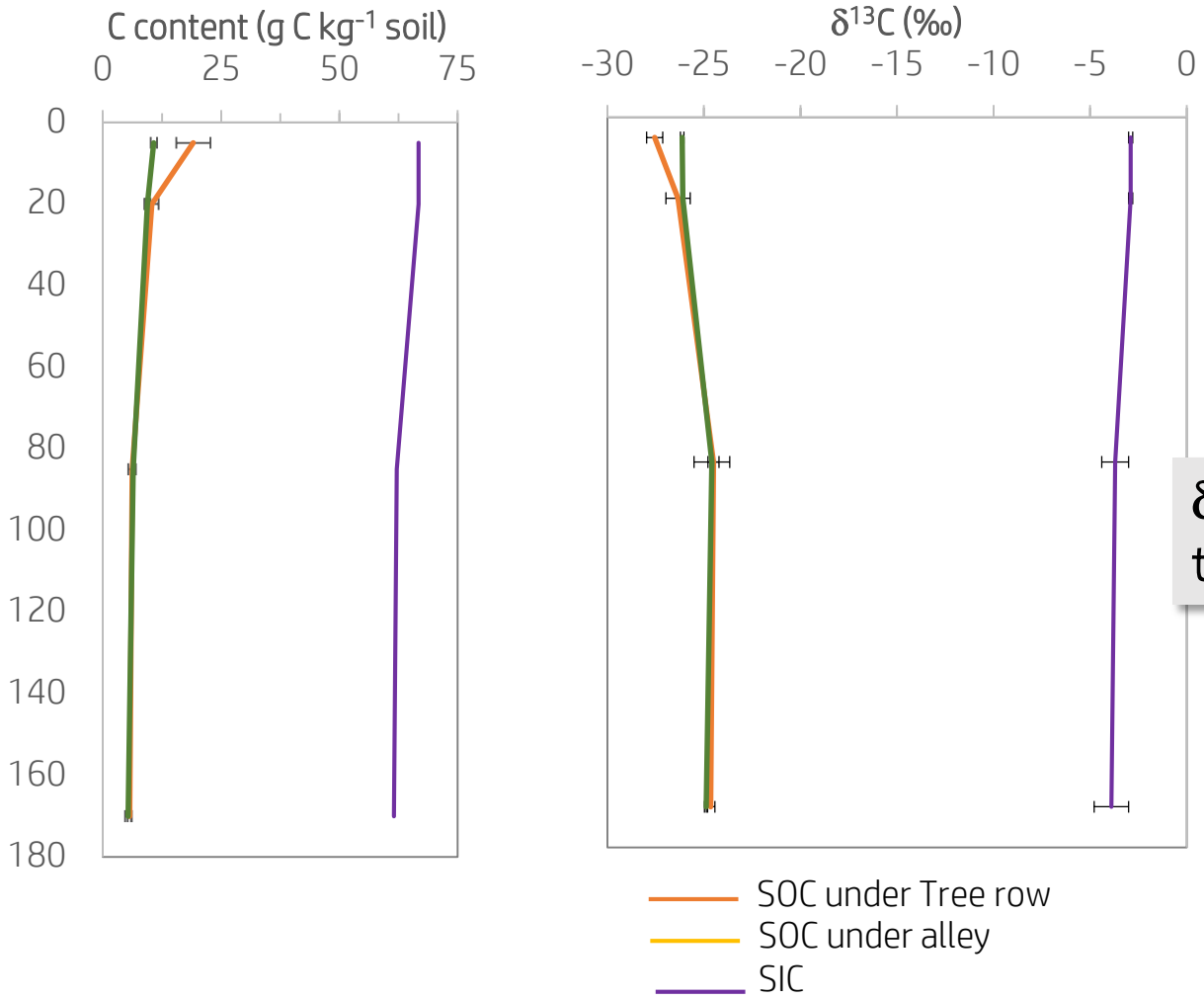
SOC contents decreased with depth, especially under tree rows.

SIC content was homogeneous with soil depth and location (tree rows or alley).

SOC under Tree row
SOC under alley
SIC

SOC and $\delta^{13}C$ in Control plot was not represented as it is quite the same value as SOC and $\delta^{13}C$ in alley

Results



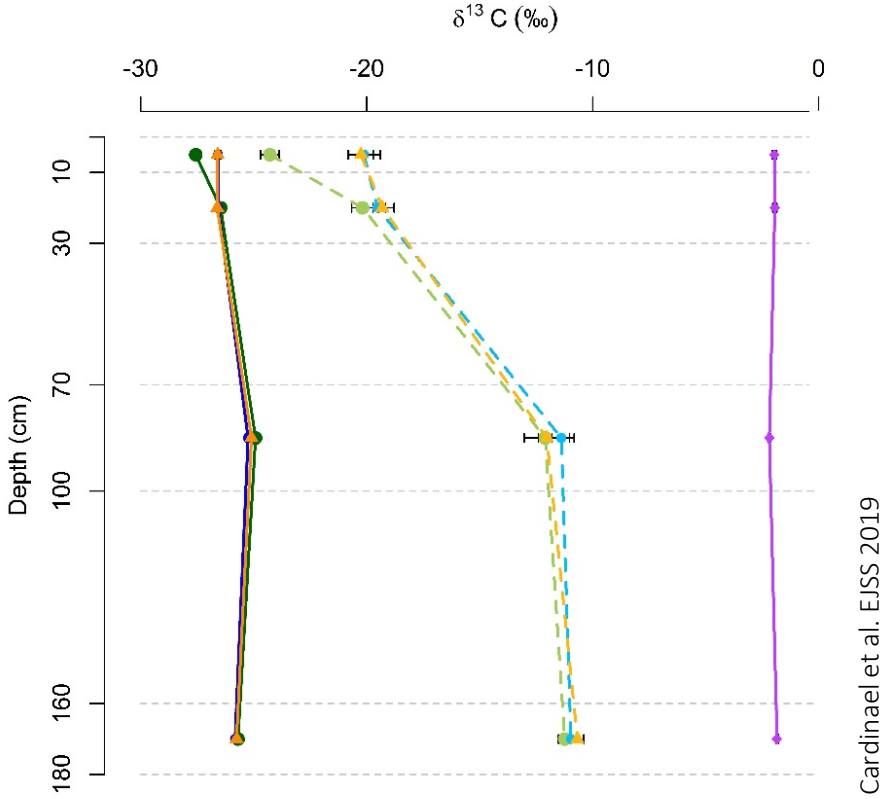
SOC contents decreased with depth, especially under tree rows.

SIC content was homogeneous with soil depth and location (tree rows or alley).

δ^{13}C-SOC and δ^{13}C-SIC differed by more than 20‰ units along the soil profile

SOC and δ^{13}C in Control plot was not represented as it is quite the same value as SOC and δ^{13}C in alley

Results

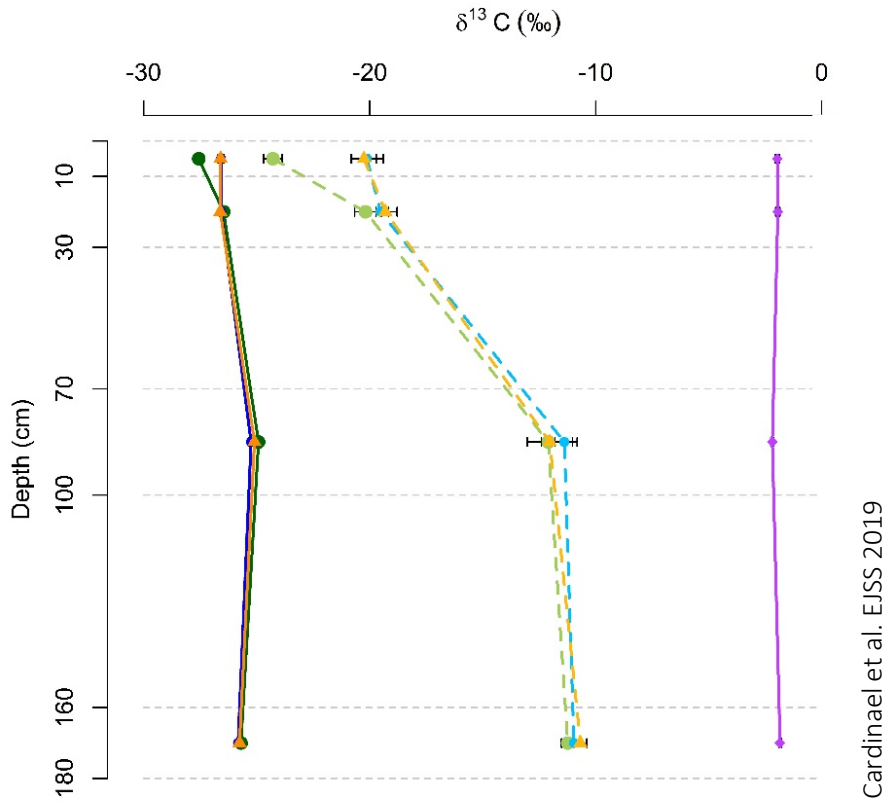


δ^{13}C-CO_2 were between the δ^{13}C-SIC and δ^{13}C-SOC

SIC and SOC contributed both to CO_2 emissions

SOC under Tree row
SOC under control (no significant differance with alleys)
CO_2 from soil at 35-44 days of incubation (tree rows ; control ; alley)
SIC

Results



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$$\delta^{13}C\text{-}CO_2 = f_{SIC}\,\delta^{13}C\text{-}SIC + (1-f_{SIC})\,\delta^{13}C\text{-}SOC$$

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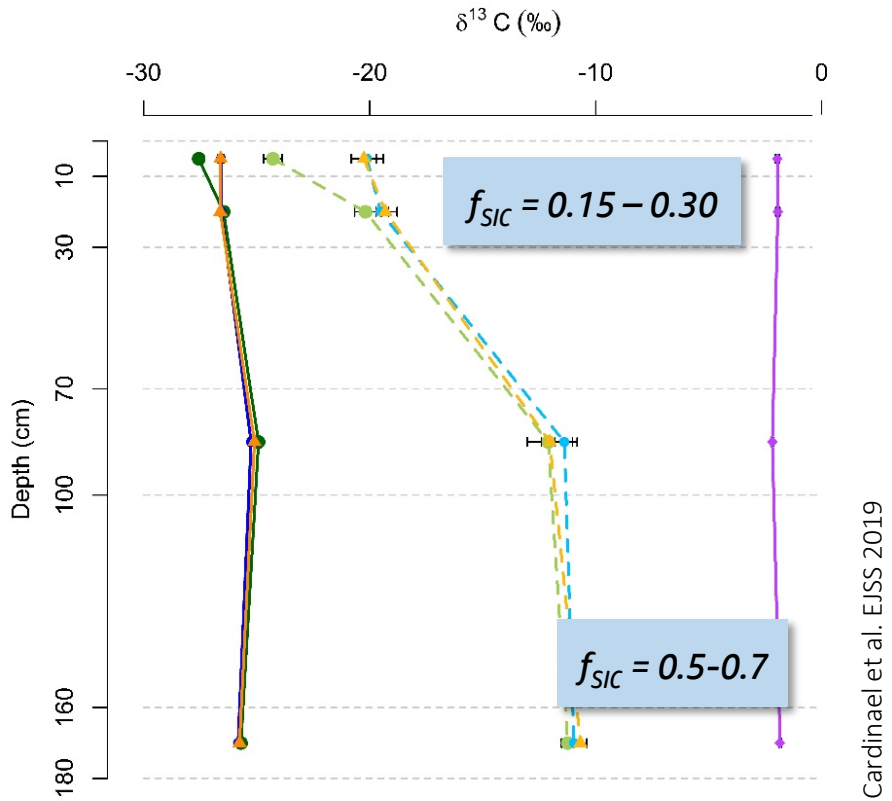
SIC

Results



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SIC and SOC contributed both to CO_2 emissions

$$\delta^{13}C\text{-}CO_2 = f_{SIC}\ \delta^{13}C\text{-}SIC + (1\text{-}f_{SIC})\ \delta^{13}C\text{-}SOC$$

δ^{13}C-CO_2 increased with soil depth

f_{SIC} *i.e.* contribution of SIC to CO2 emissions, **increased with depth**

SOC under Tree row

SOC under control (no significant differance with alleys)

CO_2 from soil at 35-44 days of incubation (tree rows ● ; control ● ; alley ●)

SIC

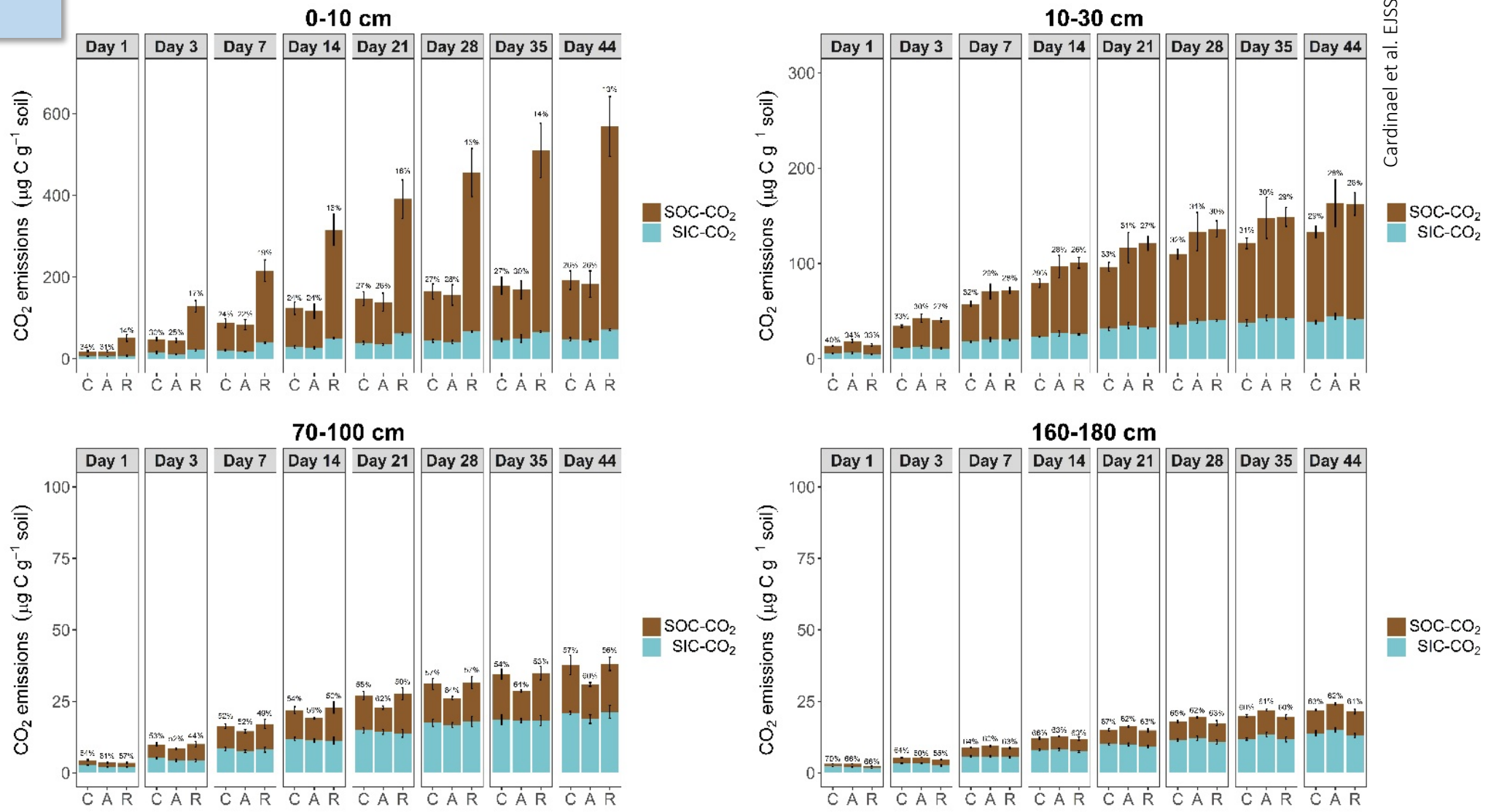
Results

$CO_2 = SIC\text{-}CO_2 + SOC\text{-}CO_2$

$SOC\text{-}CO_2 = (1 - f_{SIC}) \times CO_2$

$SIC\text{-}CO_2 = f_{SIC} \times CO_2$

C: Control
A: Alley
R : Tree Rows



Cardinael et al. EJSS 2019

Results

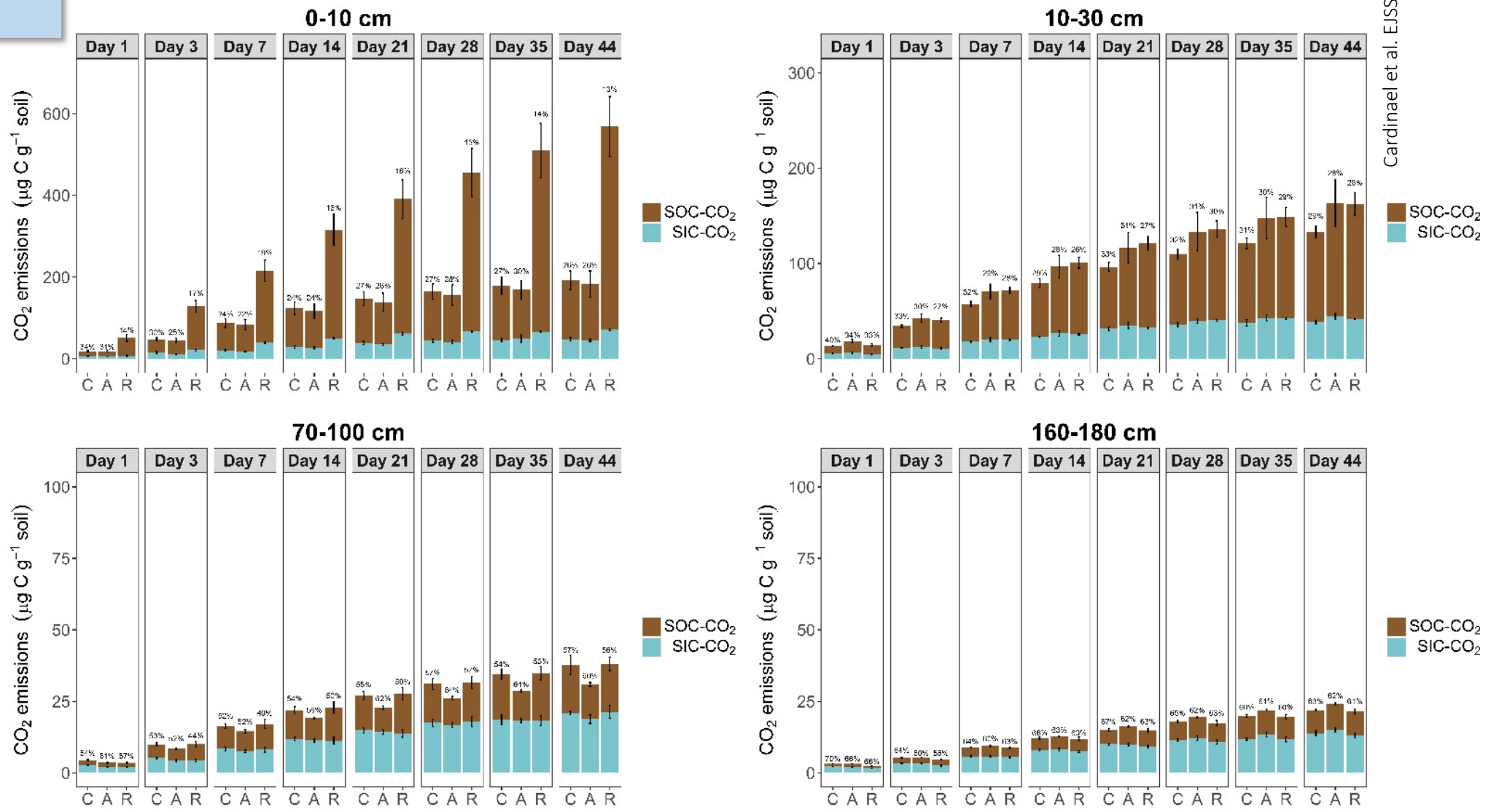
$CO_2 = SIC\text{-}CO_2 + SOC\text{-}CO_2$

$SOC\text{-}CO_2 = (1 - f_{SIC}) \times CO_2$

$SIC\text{-}CO_2 = f_{SIC} \times CO_2$

Kinetics of $SOC\text{-}CO_2$ and $SIC\text{-}CO_2$ showed that the contribution of $SIC\text{-}CO_2$ to CO_2 emissions was significant during all the incubation period

C: Control
A: Alley
R : Tree Rows



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At 0-10 cm
CO_2, SOC-CO_2 and SIC-CO_2
were much higher under tree rows

C: Control
A: Alley
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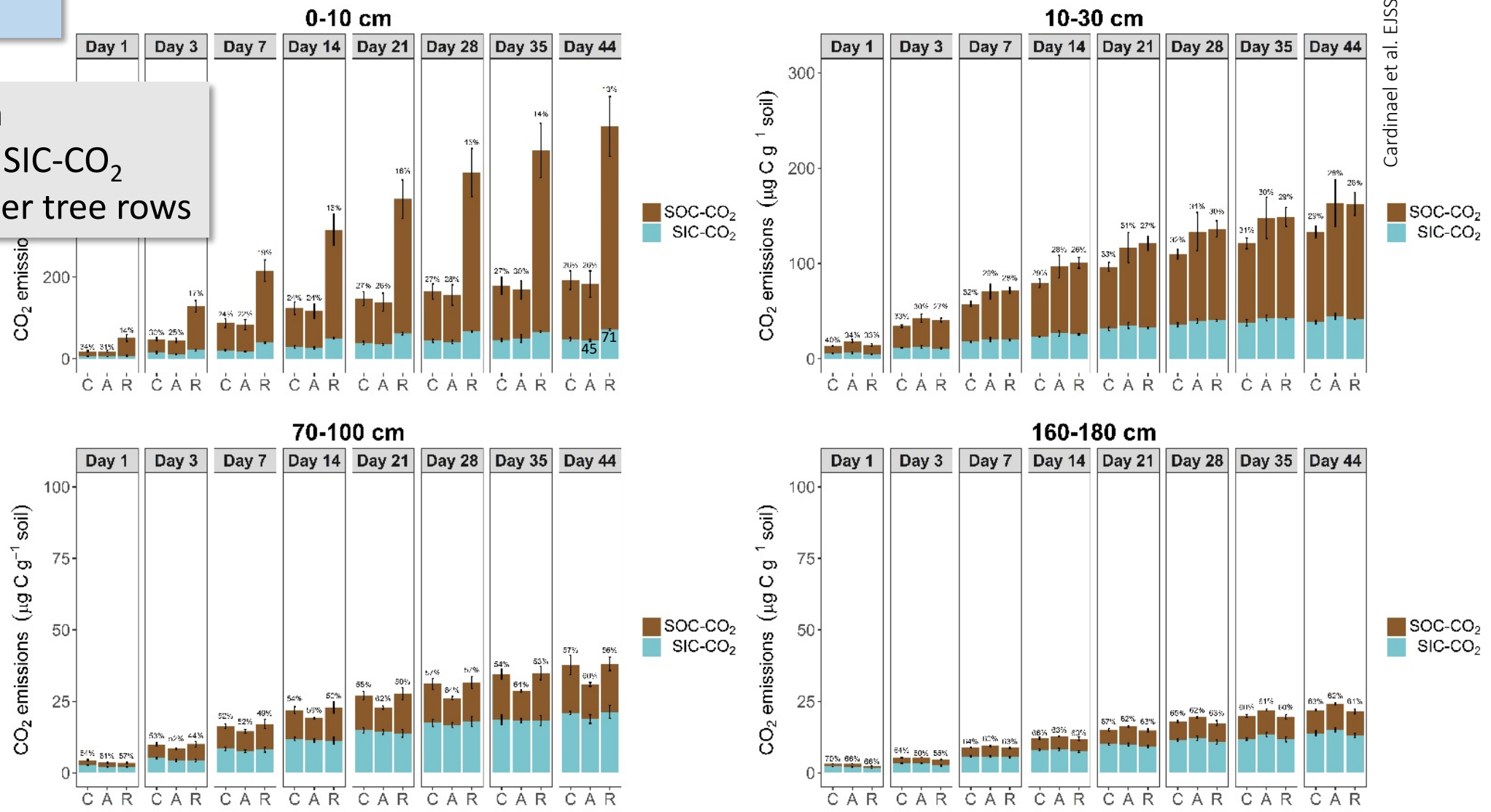

Cardinael et al. EJSS 2019

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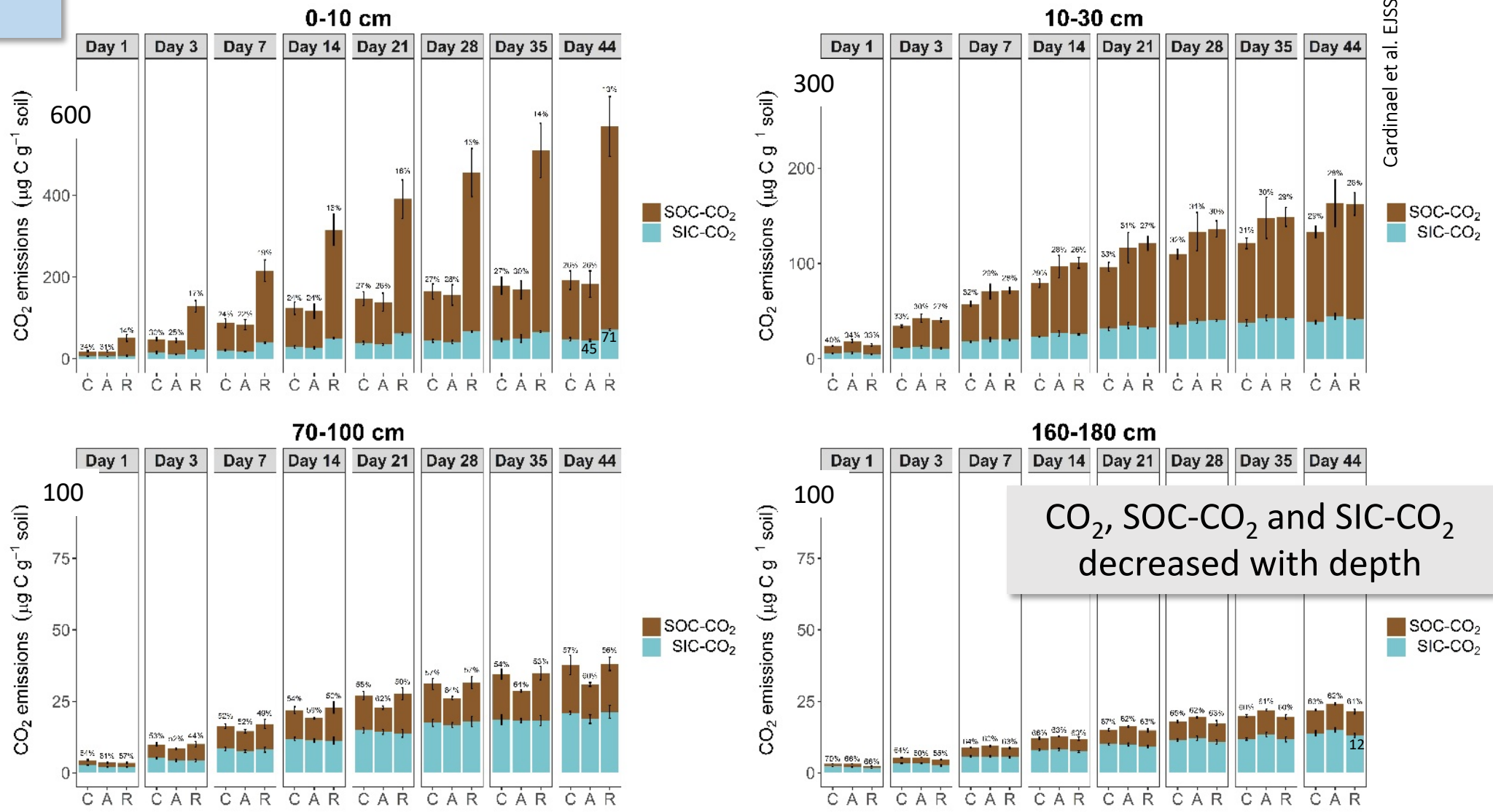

Cardinael et al. EJSS 2019

CO_2, $SOC\text{-}CO_2$ and $SIC\text{-}CO_2$ decreased with depth

Results

$CO_2 = SIC\text{-}CO_2 + SOC\text{-}CO_2$

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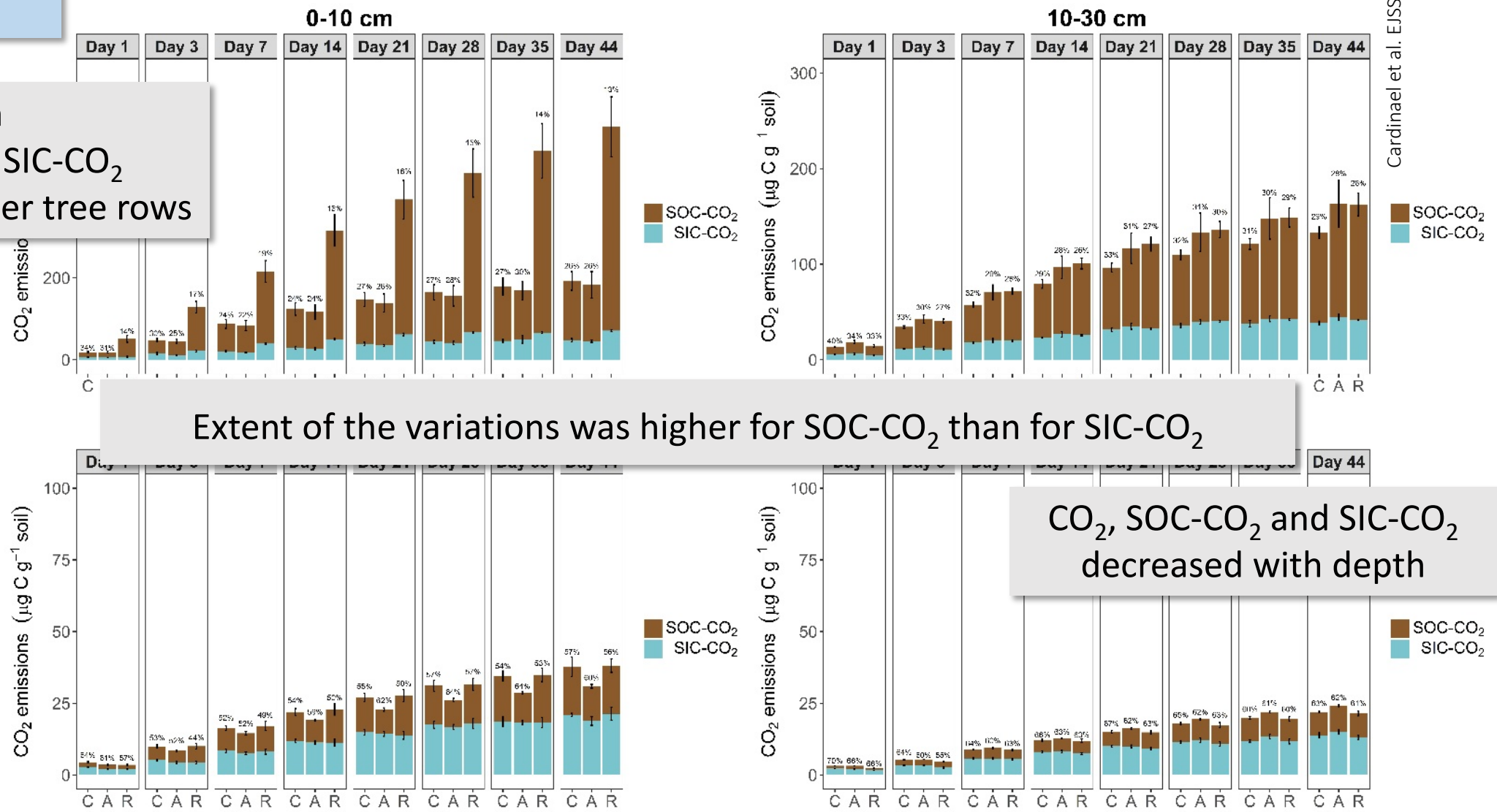
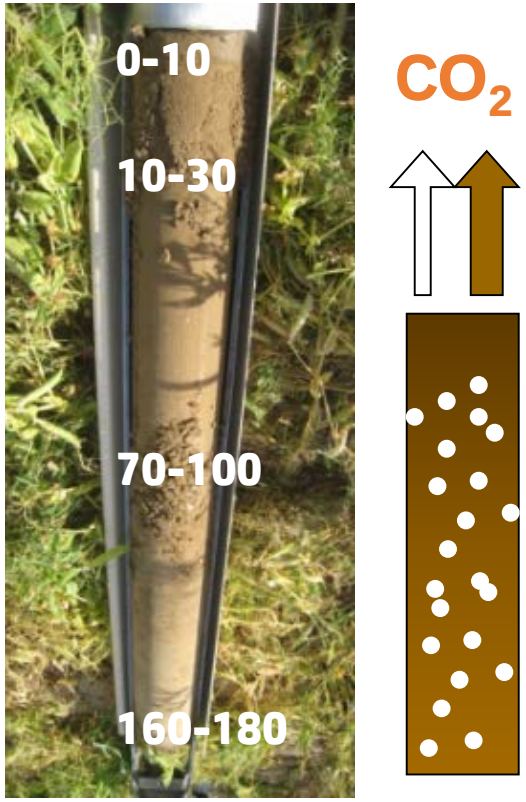


Extent of the variations was higher for SOC-CO_2 than for SIC-CO_2

CO_2, SOC-CO_2 and SIC-CO_2
decreased with depth

Discussion

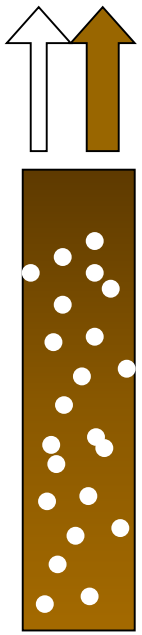


If SIC contributes to CO2 emissions, is this contribution homogeneous along the soil profile?

Does depth impact SOC and SIC dynamics in the same way?

Is there a correlation between SOC and SIC dynamics ?

Discussion



SIC-CO_2 = f_{SIC} x CO_2

f_{SIC} increased with soil depth

If SIC contributes to CO2 emissions, is this contribution homogeneous along the soil profile?

f_{SIC} = 0.15 – 0.30

f_{SIC} = 0.5-0.7

Does depth impact SOC and SIC dynamics in the same way?

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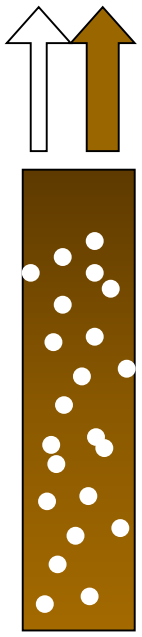
Discussion



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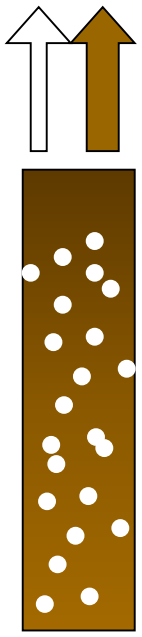
SOC, microbial biomass and CO_2 decreased with soil depth

SOC-CO2 and SIC-CO2 decreased with soil depth

Higher decrease for SOC in tree rows (-95%) than for SOC in the alleys (-87%) or for SIC (about -80%)

Discussion



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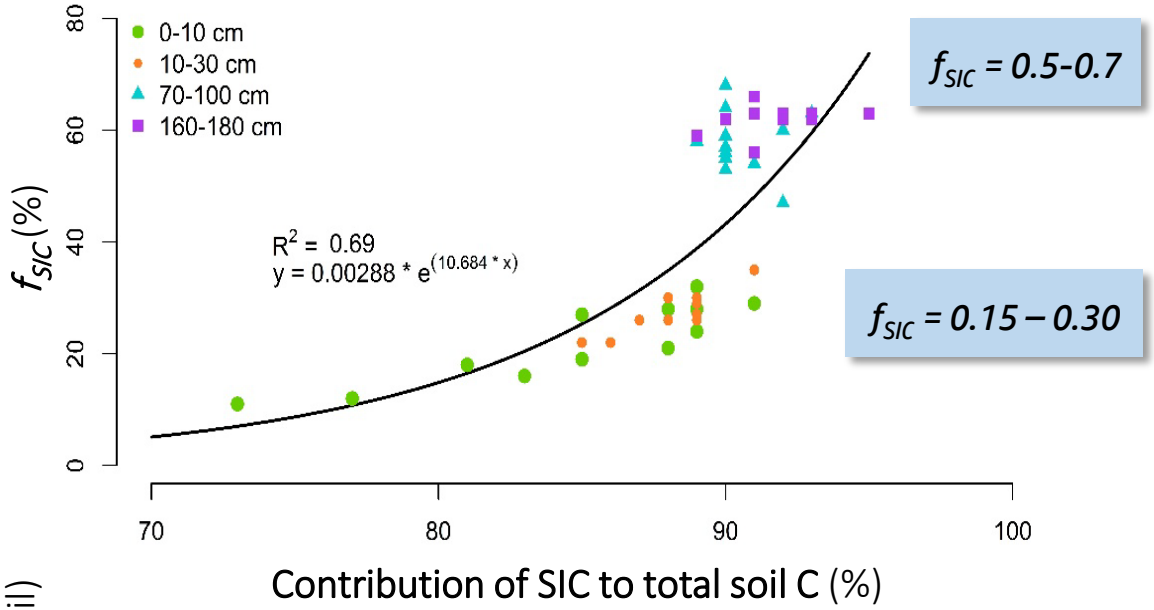
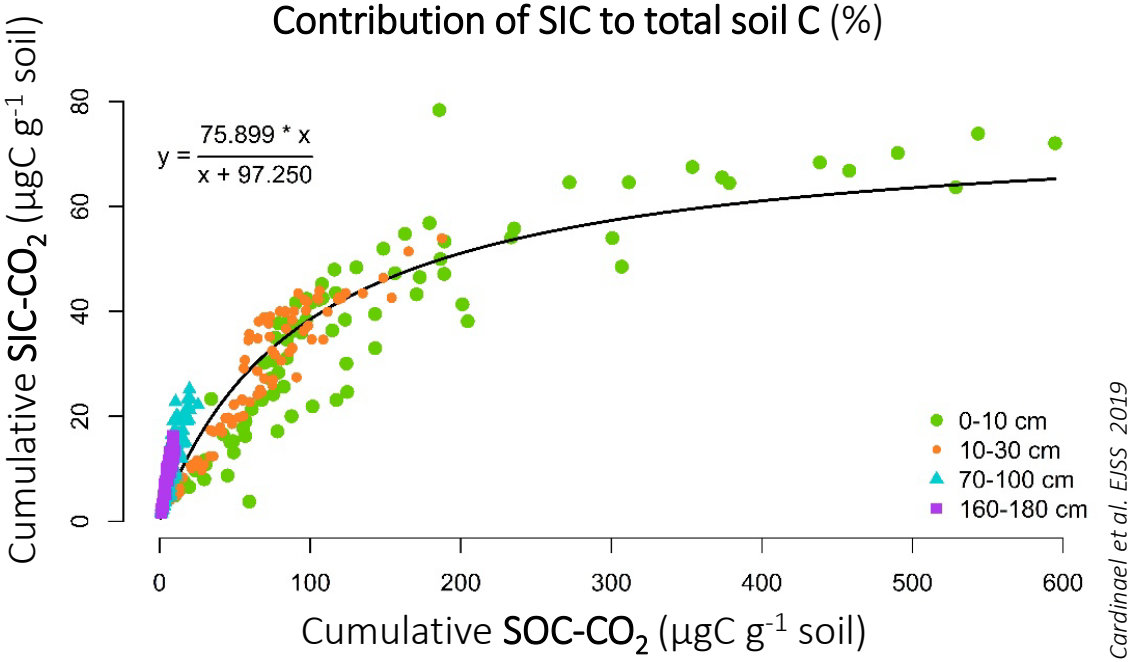
f_{SIC} increased with soil depth as the contribution of SIC to total C increased with depth. However, there was no linear correlation between f_{SIC} and the contribution of SIC to the total C content.



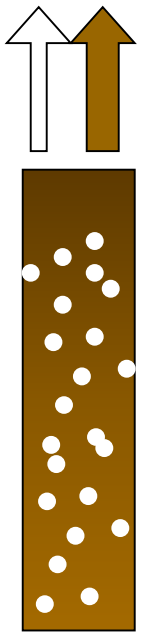
SOC-CO_2 and SIC-CO_2 emissions were linked

The more CO_2 was emitted by biological activities, the more CO_2 was emitted from the SIC



Cardinael et al. EJSS 2019

Discussion



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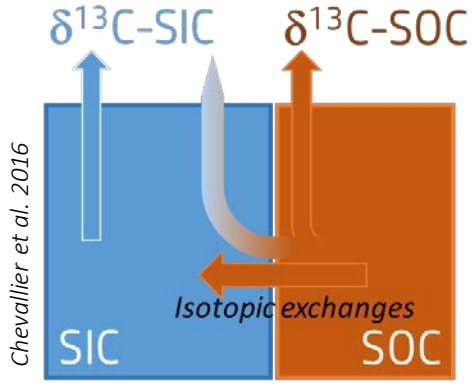
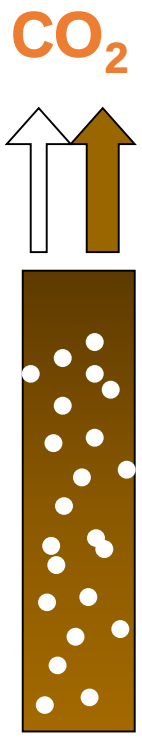


Links between SOC- and SIC- CO2

Conclusion



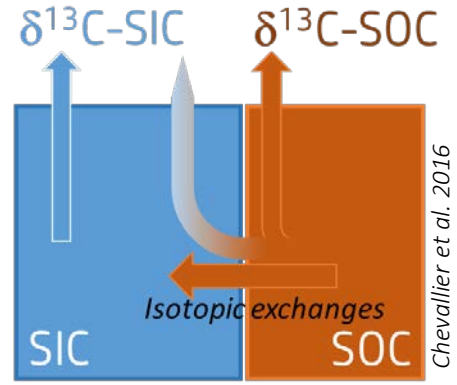
In calcareous soils, total CO_2 values could overestimate soil respiration if the isotopic signature of the CO_2 is not taken into account.

SIC contributes to CO_2 emissions especially in soil deep horizons

SIC-CO_2 and SOC-CO_2 decrease with soil depth

There is a strong correlation between SIC and SOC emissions

To go beyond this result, more in-depth studies on carbonate dissolution-precipitation processes and their impact on CO_2 emissions are needed.
(Disentangle SOC and SIC dynamics with C isotopie, soil sterilization or O_2 exchanges…)



EGU General Assembly 2020

Contribution of inorganic carbon to CO_2 emissions under a Mediterranean agroforestry system

Please if interested in our work,

Contact us : tiphaine.chevallier@ird.fr or remi.cardinael@cirad.fr

The main results of this presentation come from Cardinael et al. 2019, Eur J Soil Sci, https://doi.org/10.1111/ejss.12908.

All the references quoted in the presentation are listed on the next slide

Institut de Recherche pour le Développement FRANCE

cirad LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

AgroParisTech INSTITUT DES SCIENCES ET INDUSTRIES DU VIVANT ET DE L'ENVIRONNEMENT PARIS INSTITUTE OF TECHNOLOGY FOR LIFE, FOOD AND ENVIRONMENTAL SCIENCES

INRAE la science pour la vie, l'humain, la terre

References

Bertrand, I., Delfosse, O., &Mary, B. 2007. Carbon and nitrogen mineralization in acidic, limed and calcareous agricultural soils: Apparent and actual effects. *Soil Biology and Biochemistry* **39**, 276–288. https://doi.org/10.1016/j.soilbio.2006.07.016

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