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 17-20 June, 2019, Poitiers, France

Assessing and mapping SOC storage and sequestration potential at national level: two different and complementary approaches

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Food security and climate change:
4 per 1000 initiative new tangible global challenges



Outline

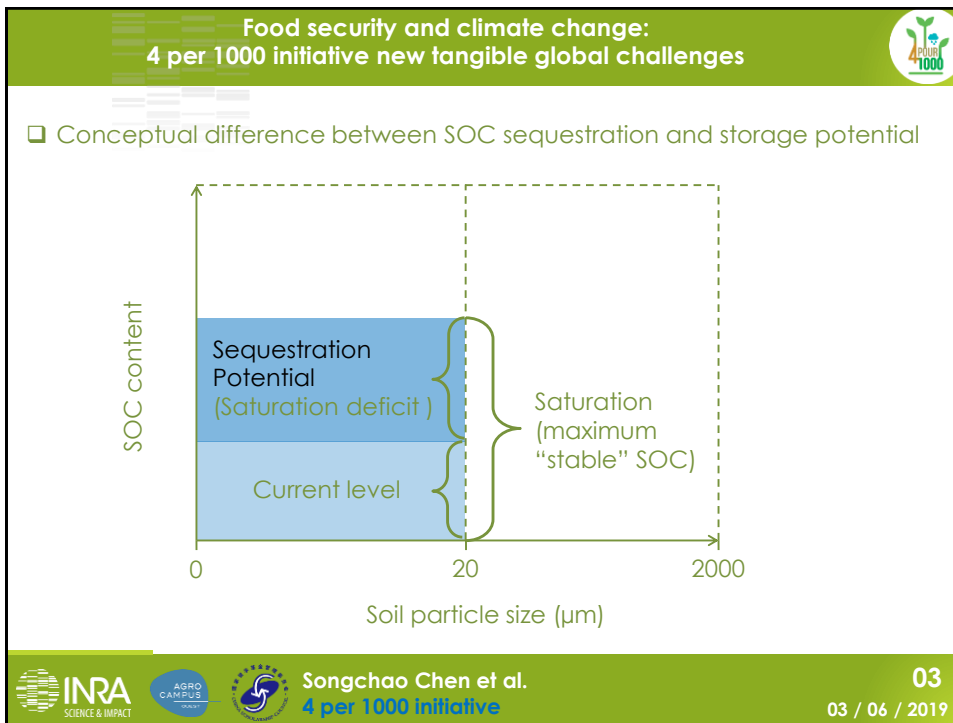
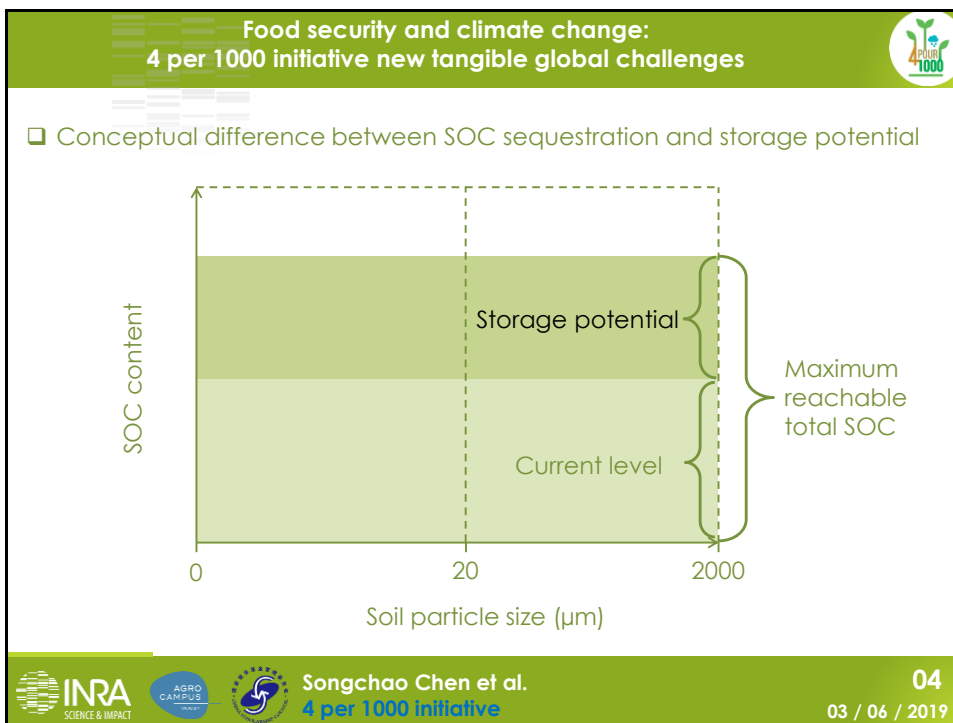
- ❑ 1. SOC **sequestration potential** using digital soil mapping
- ❑ 2. SOC **storage potential** using data-driven approach
- ❑ 3. Perspectives





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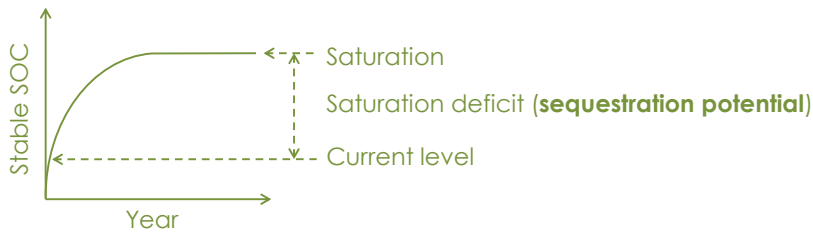
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1. SOC sequestration potential using digital soil mapping



- Hypothesis: Soil has a **maximum capacity** to store stable SOC



- Hassink's (1997) equation** (on temperate soils)

$$SOC_{sat} = 4.09 + 0.37 \times \text{FineFraction} \text{ (particle size } < 20 \mu\text{m)}$$

$$SOC_{seq_pot} = SOC_{sat} - SOC_{FineFraction}$$



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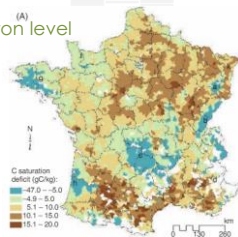
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1. SOC sequestration potential using digital soil mapping



(A)
Canton level



Angers et al. (2011)

	Area _{sat} (km ²)	Area _{unsat} (km ²)	C _{seq} (t ha ⁻¹)	C _{seq-0-10} (Mt)	C _{seq-A} (Mt)
Cropland (C)	105	22817	13.9	32	96
Grassland (G)	458	9267	6.7	6	12
Forest (F)	11561	11699	3.1	4	4
Other use (O)	3104	11312	7.9	9	22
Total	15228	55095		50	134

Wiesmeier et al. (2014)

- It has been criticized for the fact that it has **never been truly validated** and its **relationship with land cover change and management practices remains not evaluated**.
- However, it is **the best possible approach** currently for large scale mapping before **other alternative indicators** (rapid and inexpensive) are created.



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1. SOC sequestration potential using digital soil mapping





French Soil Monitoring Network (RMQS)

2092 sampling sites (16 km grid sampling)

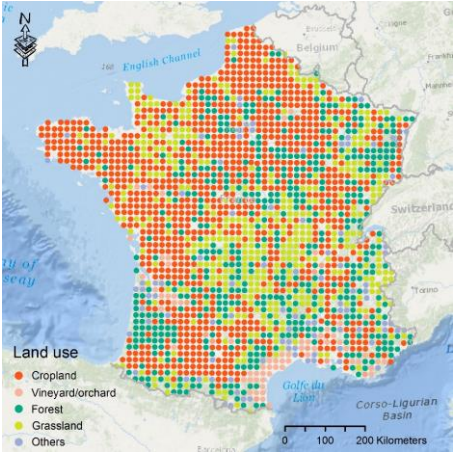
0-30 and 30-50 cm

SOC

Bulk density

Coarse elements (gravel content)

Soil particle-size distribution (0-2, 2-20, 20-50, 50-200, 200-2000 μm)



Land use

- Cropland
- Vineyard/orchard
- Forest
- Grassland
- Others

Chen et al., 2018, Fine resolution map of top- and subsoil carbon sequestration potential in France. Sci. Tot. Env.



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1. SOC sequestration potential using digital soil mapping



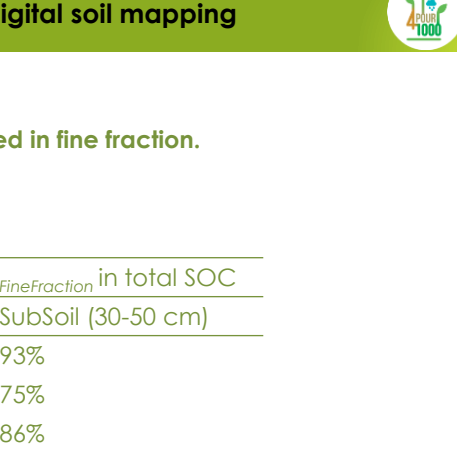


We only have total SOC, no SOC stored in fine fraction.

□ Literature review

Land use	Proportion of SOC _{FineFraction} in total SOC	
	Topsoil (0-30 cm)	SubSoil (30-50 cm)
Cropland	85%	93%
Forest	66%	75%
Grassland	69%	86%
Others	73%	85%

Compiled from related studies from countries with similar climate to France



Land use

- Cropland
- Vineyard/orchard
- Forest
- Grassland
- Others

Chen et al., 2018, Fine resolution map of top- and subsoil carbon sequestration potential in France. Sci. Tot. Env.



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1. SOC sequestration potential using digital soil mapping

❖ Mapping SOC sequestration potential

❑ Digital Soil Mapping

$S = f(s, c, o, r, p, a, n) + \epsilon$
(McBratney et al., 2003)

S, soil classes or attributes; **s**, soil;
c, climate; **o**, organisms; **r**, relief;
p, parent material; **a**, age;
n, spatial position; **ε**, residual

❑ Regression Kriging

1) Build regression model by Random Forest;
2) Ordinary kriging on regression residuals;
3) Merge regression prediction and kriged residuals for final output

Covariates	Scorpan factors	Resolution/scale
Precipitation	Climate	1000 m
Temperature	Climate	1000 m
NPP	Organisms	1000 m
Corine Land cover	Organisms	250 m
Soil type	Soil	1:1000000
Erosion rates	Soil	1:1000000
Parent material	Parent material	1:1000000
Elevation	Relief	90 m
Aspect	Relief	90 m
Slope	Relief	90 m
Curvature	Relief	90 m
Exposition	Relief	90 m
Roughness	Relief	90 m
Compound Topographic Index	Relief	90 m
Topographic Wetness Index	Relief	90 m

Chen et al., 2018. Fine resolution map of top- and subsoil carbon sequestration potential in France. Sci. Tot. Env.



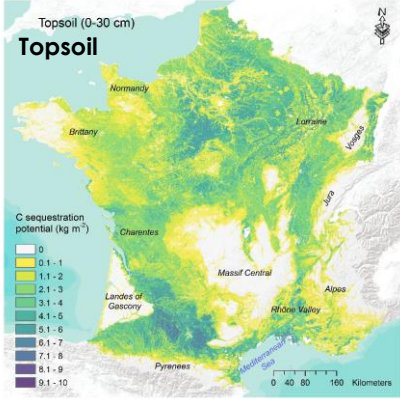
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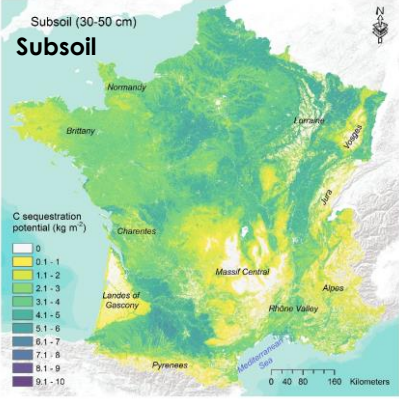
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❑ Mapping SOC sequestration potential

Topsoil (0-30 cm)



Subsoil (30-50 cm)



Chen et al., 2018. Fine resolution map of top- and subsoil carbon sequestration potential in France. Sci. Tot. Env.



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1. SOC sequestration potential using digital soil mapping



□ SOC sequestration potential stocks (Mt)

Land cover	Topsoil 0-30cm	Subsoil 30-50 cm	Area km ²
Arable land	695 (69%)	793 (58%)	225,519 (43%)
Forest	120	237	138,572
Grassland	132	238	97,736
Others	61	92	52,049
Total	1008	1360	527,159

High theoretical potential to increase SOC in subsoil by managing deeper layers:

- 1) plant species or cultivars with deeper and thicker root systems?
- 2) promoting soil faunal activities?
- 3) manage subsoil microorganisms?

Chen et al., 2018. Fine resolution map of top- and subsoil carbon sequestration potential in France. Sci. Tot. Env.



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2. SOC storage potential using data-driven approach





Increase SOC by **4% per year** in the top 30-40 cm of soils

Improve the food security, ecosystem services, adapt and mitigate climate change

In the context of 4p1000, SOC increase refers to the whole soil.

Data driven approach

The highest possible values under a specific land use/cover or land management practices for each pedo-climatic condition

(Barré et al., 2017)



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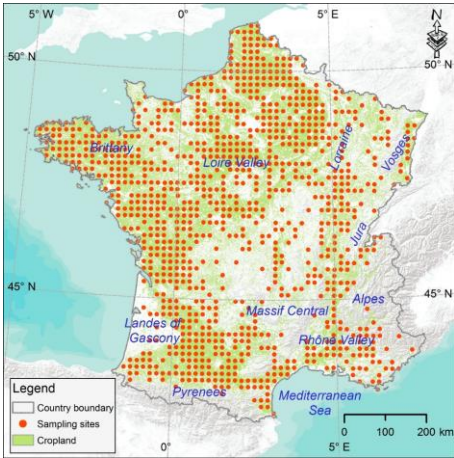
2. SOC storage potential using data-driven approach

□ Data driven approach

1) Determine carbon-landscape zones by clustering (NPP, Climate and clay)

2) Estimate maximum SOC stocks in **arable soils** for each carbon-landscape zones using four percentiles (0.8, 0.85, 0.9, 0.95)

3) Estimate SOC storage potential by the difference between maximum and current SOC stocks under four percentiles



1093 **arable soils** in RMQS dataset

Chen et al., 2019. National estimation of soil organic carbon storage potential for arable soils: A data-driven approach coupled with carbon-landscape zones. Sci. Tot. Env.



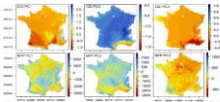
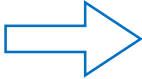
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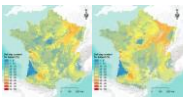
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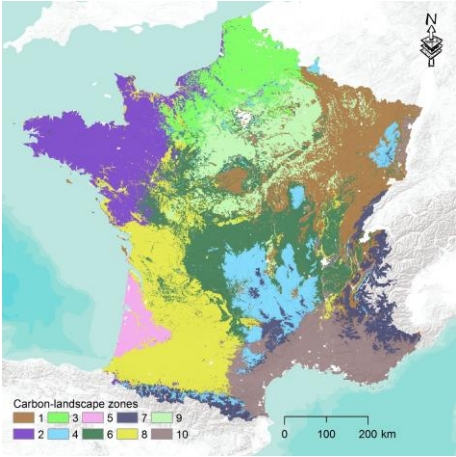
□ Carbon-landscape zones using Gaussian mixed model

Net Primary Production (MODIS)
Climatic decomposition index
(Carol Adair et al. 2008)



Soil clay maps (topsoil and subsoil)





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2. SOC storage potential using data-driven approach

Current SOC stock maps (Digital Soil Mapping)

Topsoil SOC stocks

Current SOC stocks for topsoil (kg m⁻²)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- 10 - 15
- > 15

Subsoil SOC stocks

Current SOC stocks for subsoil (kg m⁻²)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 8
- 8 - 10
- 10 - 15
- > 15
- Non-subsoil

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2. SOC storage potential using data-driven approach

Maximum SOC under each CLZ for French arable soils (90% CIs using bootstrapping)

(a) Topsoil

Maximum SOC stocks (kg m⁻²)

Percentile

- 0.8
- 0.85
- 0.9
- 0.95

(b) Subsoil

Maximum SOC stocks (kg m⁻²)

Percentile

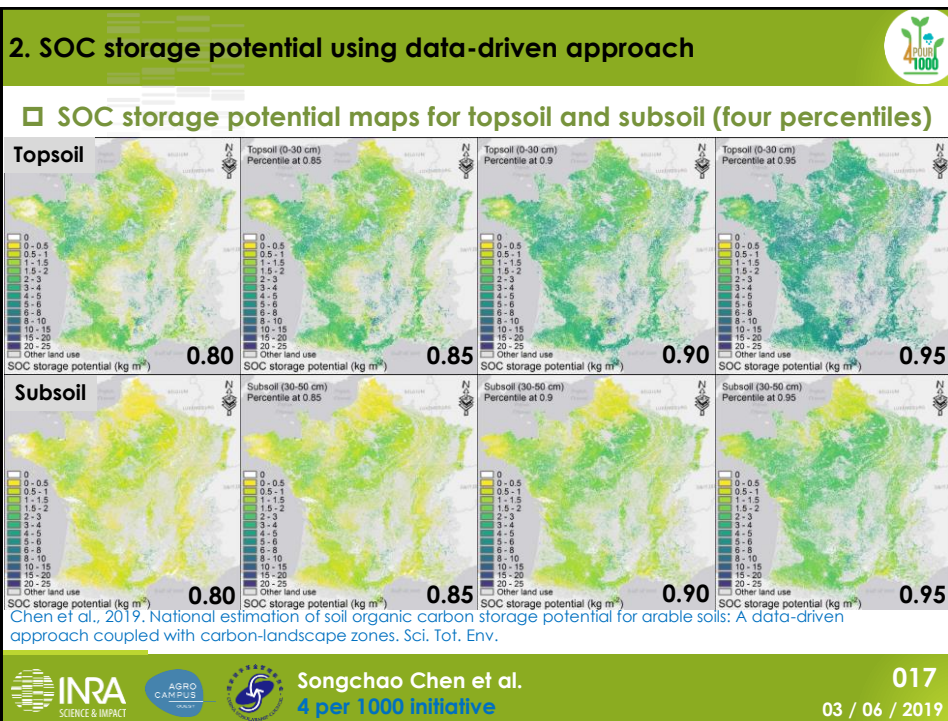
- 0.8
- 0.85
- 0.9
- 0.95

Chen et al., 2019. National estimation of soil organic carbon storage potential for arable soils: A data-driven approach coupled with carbon-landscape zones. Sci. Tot. Env.

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2. SOC storage potential using data-driven approach

□ SOC storage potential stocks of French arable soils

Soil layer	SOC storage potential under four percentiles (Mt)				Current
	0.80	0.85	0.90	0.95	
Topsoil	336 (25%)	470 (34%)	674 (49%)	1020 (74%)	1370
Subsoil	165 (38%)	228 (52%)	309 (70%)	433 (98%)	440

□ The estimates of SOC storage potential are **sensitive to the percentile chosen**, especially at high values setting (e.g., 0.95).

□ It provides an estimate of SOC storage potential **under present management practices**.

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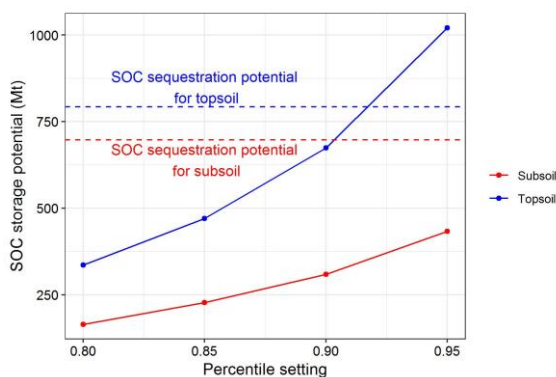
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2. SOC storage potential using data-driven approach



□ SOC sequestration

potential can be hardly reached under current management practices, especially for **subsoil**.



- This data-driven approach looks more realistic and **offers potentials for operational purposes** as it enables to set different targets for the decision makers and farmers.



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2. SOC storage potential using data-driven approach



□ Limitations of the data-driven approach

- 1) **Management practices are not documented**, and thus make it difficult to determine their influence.
- 2) Some **arable soils** may have been recently **converted from other land uses** (e.g., grassland, forest) and may not have yet reached an equilibrium.
- 3) A CLZ may include very **different agricultural production systems** and in some cases reaching the storage potential would not only require to change the management practices, but the whole production system.



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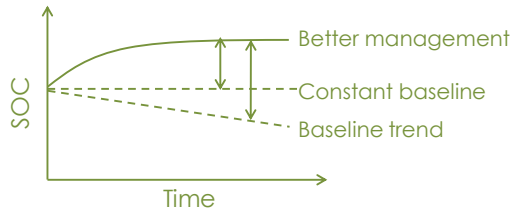
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3. Perspectives



- ❑ Estimate SOC storage potential by **model-driven approach** (e.g., soil biogeochemical models, such as CENTURY, RothC)? In turn to determine which percentile in data-driven is feasible?
- ❑ Introduce the **SOC baseline trend** into data-driven approach? And how?



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Many thanks for your attention 😊



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Climatic decomposition index (CDI, Carol Adair et al., 2008)

$$CDI = F_T(Temp) \times FW(Prec, PET)$$

$$F_T(Temp) = 0.5766 \times e^{308.56 \times (1/56.02 - 1/(273 + Temp - 227.13))}$$

$$FW(Prec, PET) = 1/(1 + 30 \times e^{-8.5 \times Prec/PET})$$

Net primary productivity

MOD17A2H version 6 Gross Primary Production product (NASA LP DAAC, 2017) from 2000 to 2010.

