



**Food security and climate change:**  
**4 per 1000 initiative new tangible global challenges**  
*17-20 June, 2019, Poitiers, France*

# Assessing and mapping SOC storage and potentiel de sequestration at national level: two different and complementary approaches

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## Outline

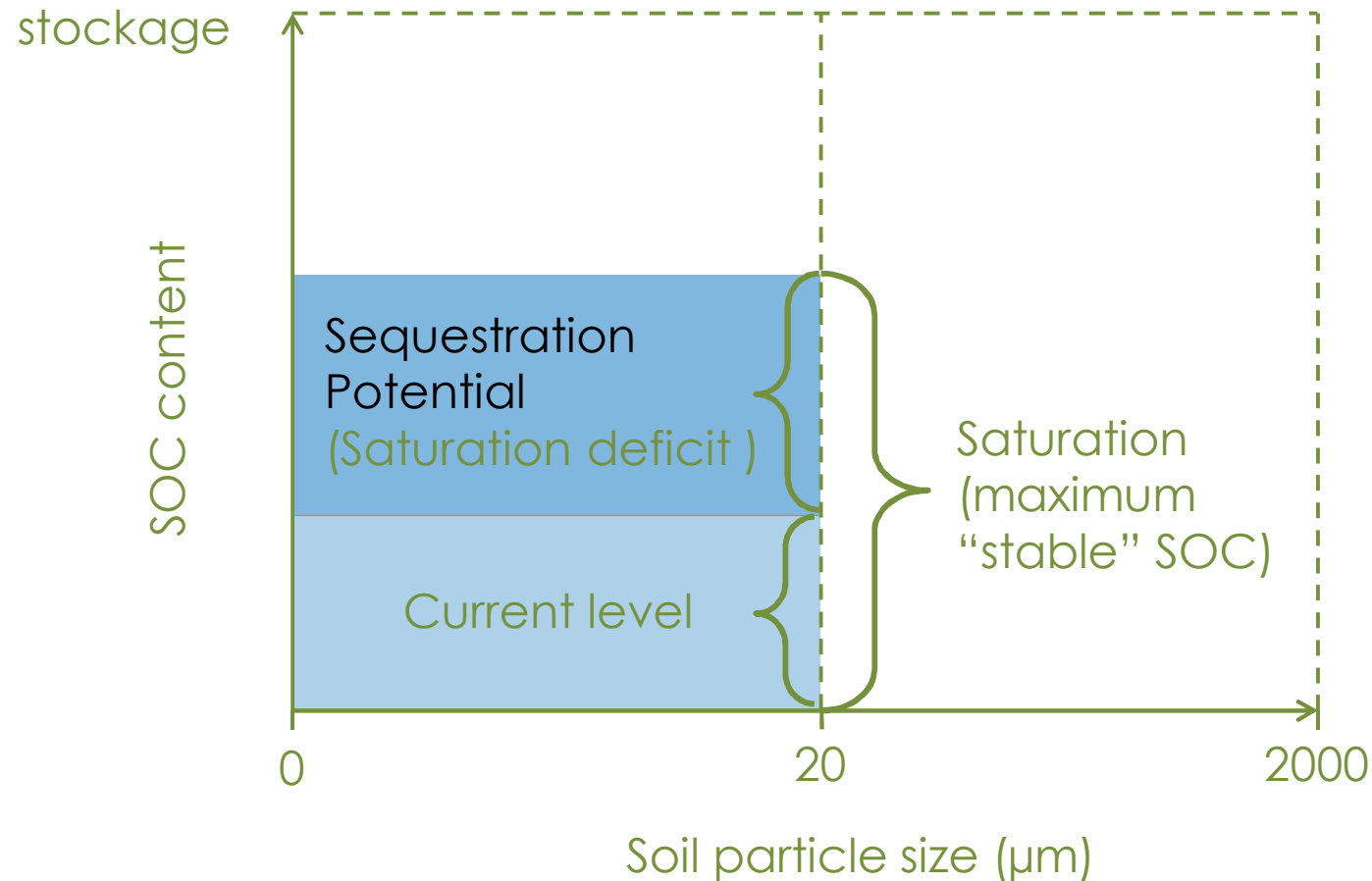
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- ❑ 1. Potentiel de séquestration de COS par cartographie numérique des sols
- ❑ 2. Estimation du stockage de COS par approche statistique
- ❑ 3. Perspectives

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



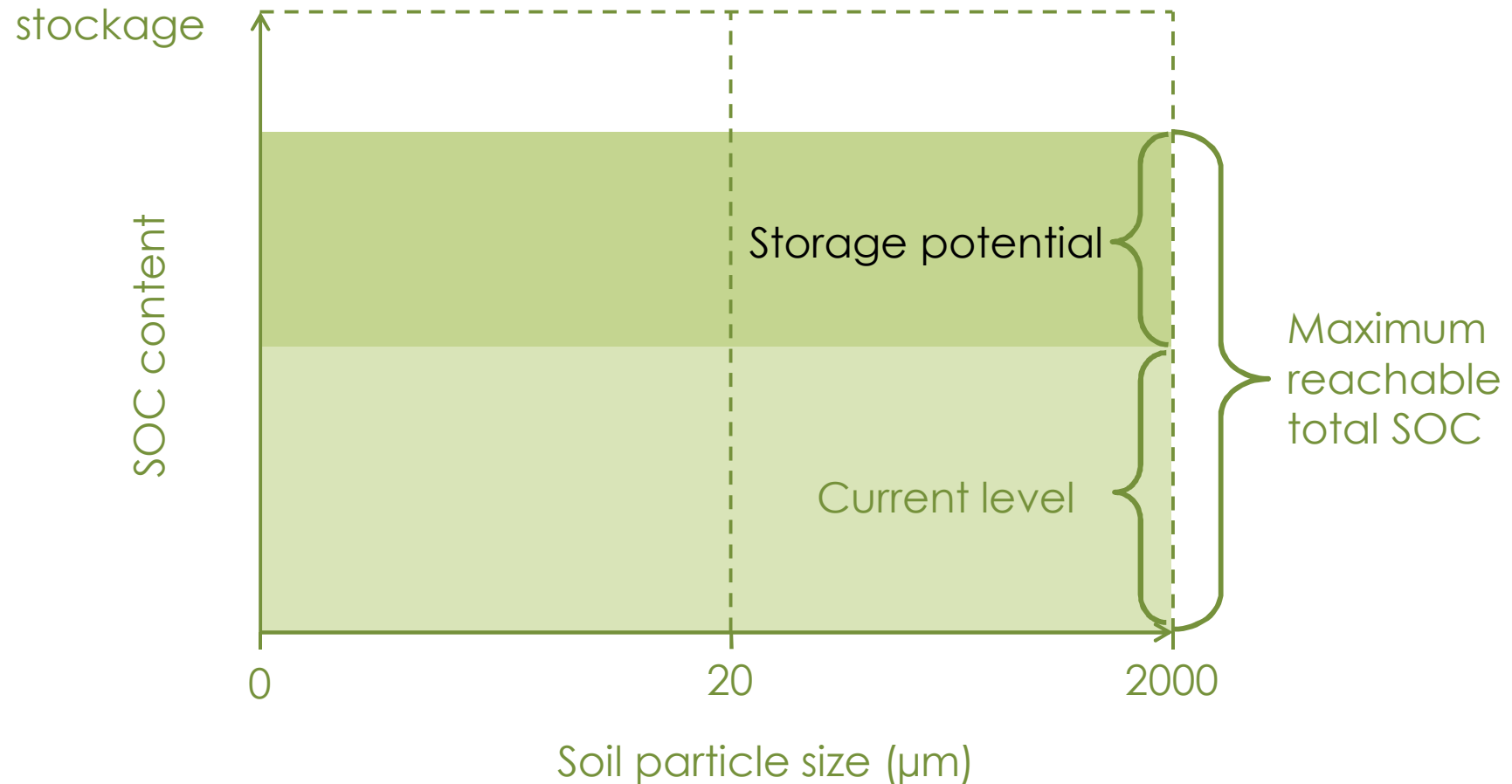
- Différence conceptuelle entre la sequestration de CO<sub>2</sub> et le potentiel de



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- ❑ Différence conceptuelle entre la sequestration de CO<sub>2</sub> et le potentiel de



## 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

Dans le contexte du 4p1000, l'augmentation du COS se réfère à l'intégralité du stock

### Approche statistique

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

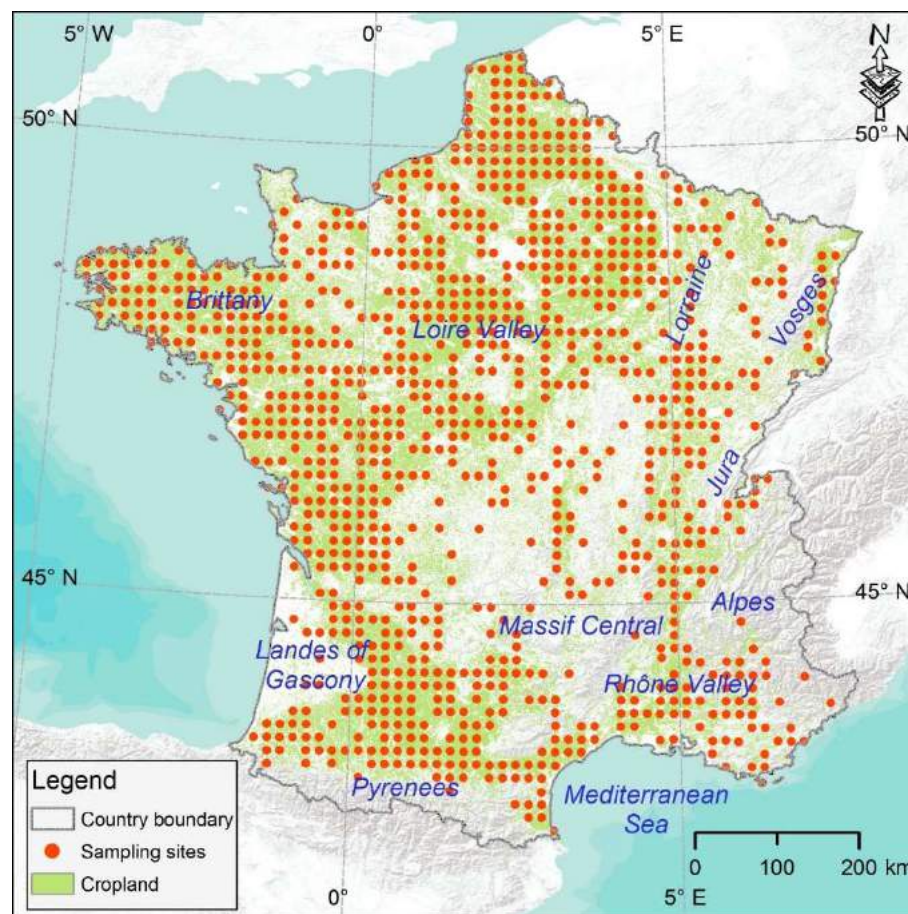
*(Barré et al., 2017)*

## 2. SOC storage potential using data-driven approach



### □ Approche statistique

- 1) Délimitation d'entités "carbon-landscape" (**CLZ**) par classification (NPP, Climate and clay)
- 2) Estimation des stocks maximaux pour les sols en cultures arables pour chaque entité à l'aide de 4 percentiles (0.8, 0.85, 0.9, 0.95)
- 3) Estimation du potentiel de stockage par différence entre la valeur maximale et le stock actuel (pour chaque percentile)



1093 **arable soils** in RMQS dataset

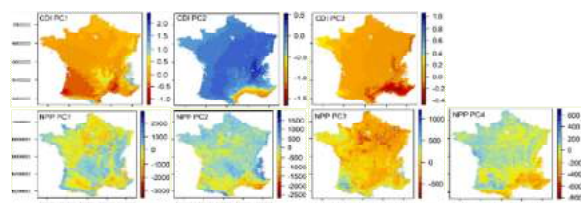
Chen et al., 2019. National estimation of soil organic carbon storage potential for arable soils: A data-driven approach coupled with carbon-landscape zones. *Sci. Tot. Env.*



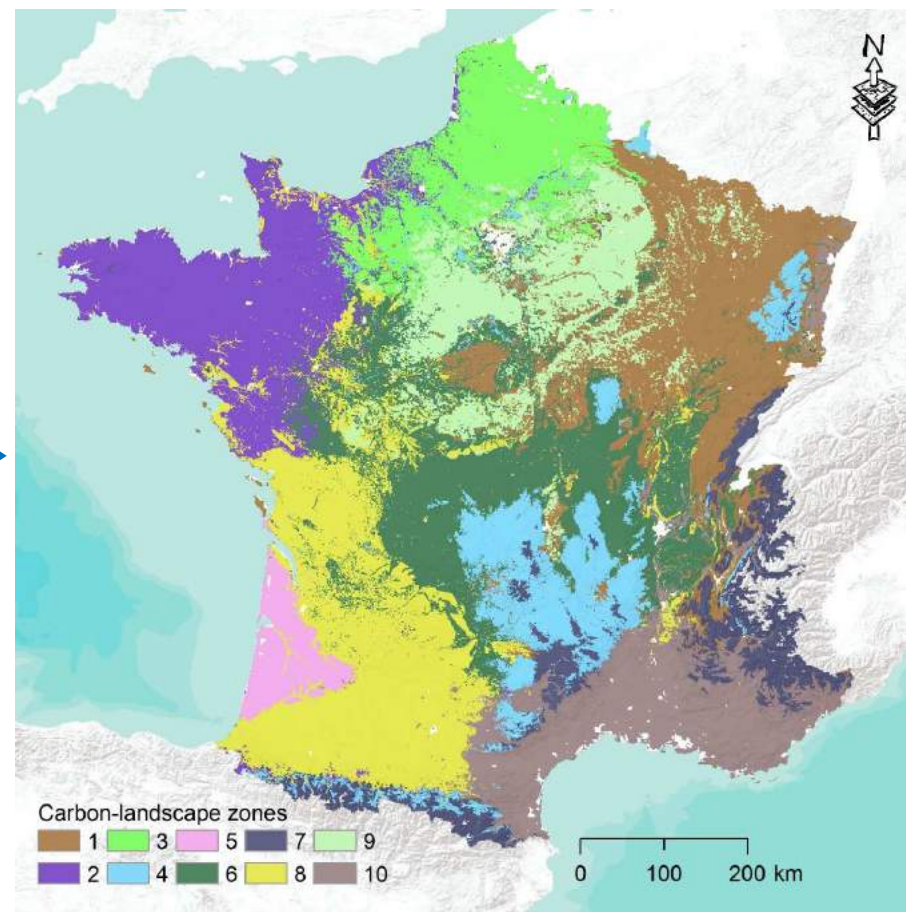
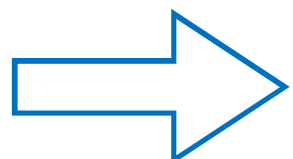
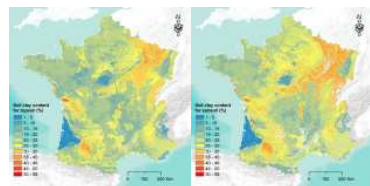
## 2. SOC storage potential using data-driven approach

### Entités Carbon-landscape (CLZ - Modèle Gaussien mixte)

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



Soil clay maps (topsoil and subsoil)

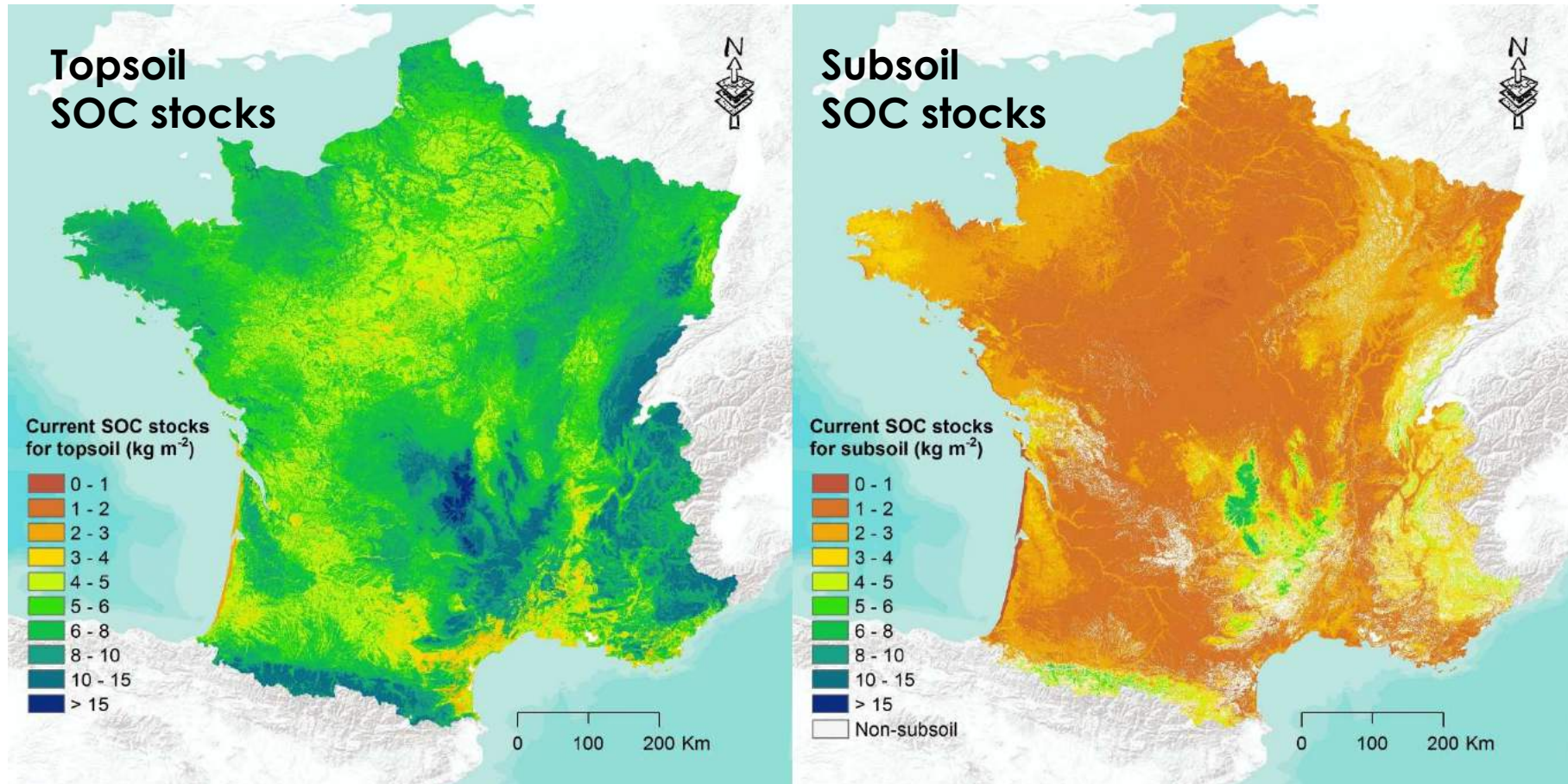


Chen et al., 2019. National estimation of soil organic carbon storage potential for arable soils: A data-driven approach coupled with carbon-landscape zones. Sci. Tot. Env.

## 2. SOC storage potential using data-driven approach



### □ Stocks de COS actuels (cartographie numérique)



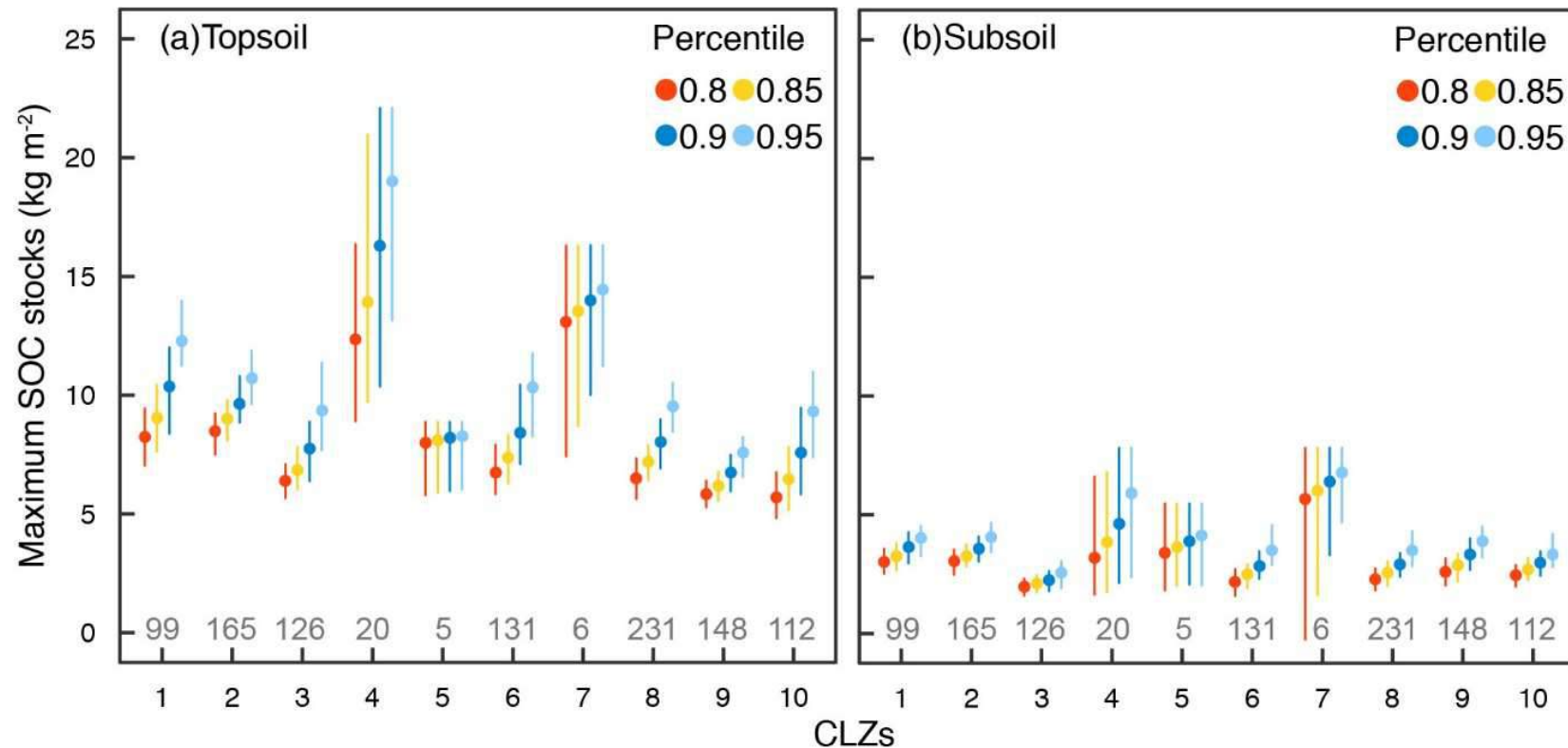
Chen et al., 2019. National estimation of soil organic carbon storage potential for arable soils: A data-driven approach coupled with carbon-landscape zones. *Sci. Tot. Env.*



## 2. SOC storage potential using data-driven approach



- Stock de COS maximal pour chaque CLZ (90% ICs par bootstrapping)

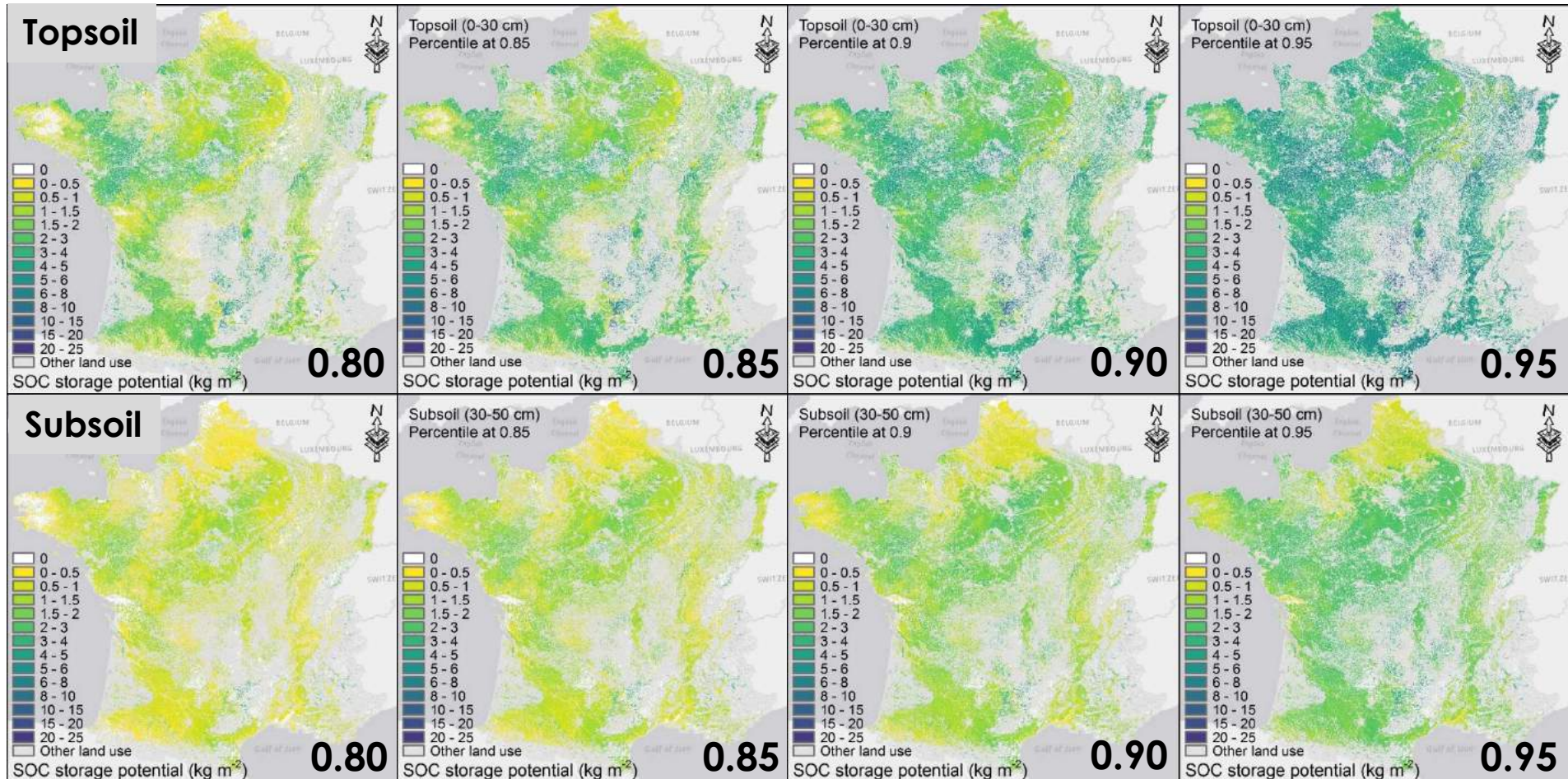


Chen et al., 2019. National estimation of soil organic carbon storage potential for arable soils: A data-driven approach coupled with carbon-landscape zones. *Sci. Tot. Env.*

## 2. SOC storage potential using data-driven approach



### □ Potentiel de stockage de COS (et quatre percentiles)



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.*

## 2. SOC storage potential using data-driven approach



### □ Potentiel de stockage de COS

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

- Les estimations du potentiel de stockage de COS dependent du quantile choisi (et tout particulièrement pour les valeurs élevées, e.g., 0.95).
- Cette valeur de potentiel ne prend en compte que les pratiques actuelles.

## 2. SOC storage potential using data-driven approach



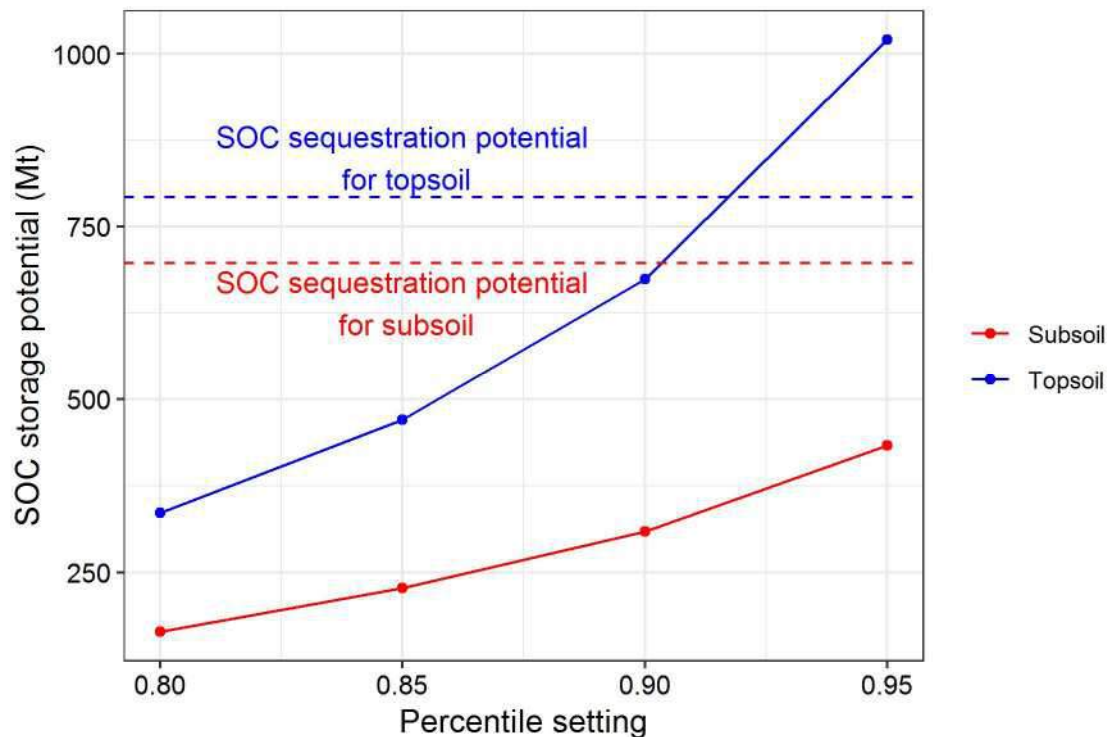
### □ Potentiel de stockage de COS et l'initiative 4 per 1000

- ❖ Les stocks actuels de COS sont de **1.37 and 1,81 Gt** (0-30 et 0-50 cm) pour les sols sous cultures en terres arables
- ❖ Pour ces sols, atteindre la cible the 4 per 1000 requièrerait un stockage de **5.48 et 7,27 Mt C an<sup>-1</sup>** (0-30 et 0-50 cm).
- ❖ A cette vitesse, il faudrait **61 (69), 85(96), 122(135) et 186 (200)** années pour atteindre le potentiel de stockage sur la couche 0-30 cm (0-50 cm) pour les quantiles **0.80, 0.85, 0.90 et 0.95**.

## 2. SOC storage potential using data-driven approach



- Il semble **difficile** d'atteindre le **potentiel de sequestration** par application des pratiques actuelles, tout particulièrement pour la couche 30-50cm



- L'approche statistique semble plus réaliste et offre des perspectives d'un point de vue opérationnel. Elle pourrait permettre de définir différentes valeurs de stockage cibles pour les aménageurs et les exploitants.

## 2. SOC storage potential using data-driven approach



### □ Limitations de l'approche statistique

- 1) **Pas d'analyse de l'effet des pratiques.** Elles sont partiellement renseignées dans les enquêtes RMQS.
- 2) Certains sols échantillonnés pourraient avoir été récemment convertis en cultures en terres arables, et refléter encore l'**ancienne occupation du sol.**
- 3) Une **CLZ** donnée pourrait inclure une grande diversité de **systèmes de cultures** et atteindre les valeurs de potential de stockage pourrait nécessiter des **changements plus profonds** que la seule application de pratiques spécifiques.

### 3. Perspectives



- ❑ Estimer les potentiels de stockage à l'aide de modèles mécanistes (e.g., des modèles biogéochimiques tels que CENTURY ou RothC)?
- ❑ Prendre en compte une possible evolution actuelle des stocks de carbone dans le calcul du potentiel?
- ❑ Redéfinir les quantiles de cette approche statistique de façon plus locale, afin de mieux répondre à des problématiques locales?



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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

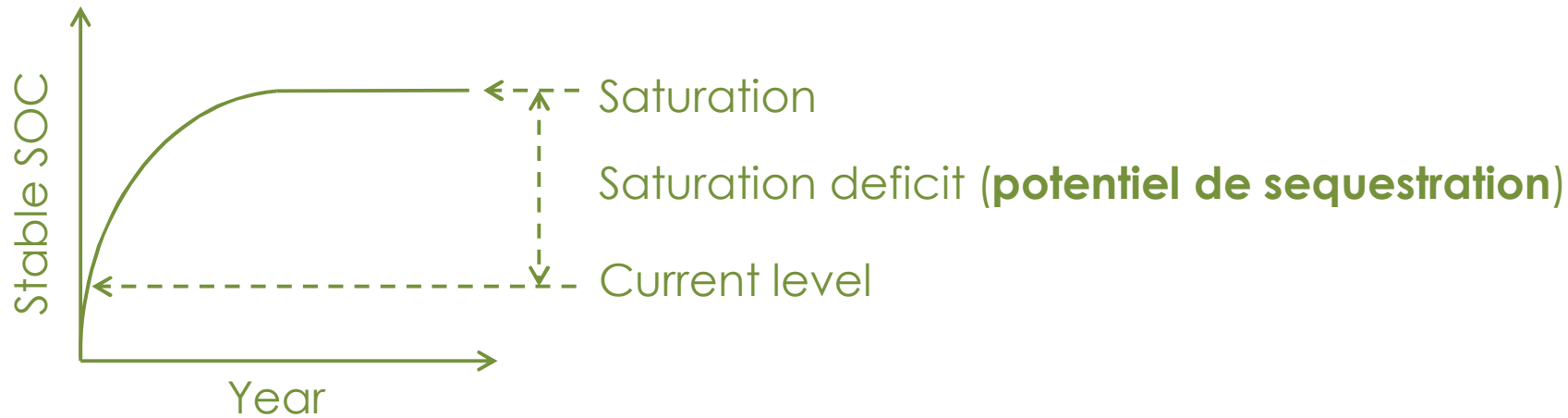
MOD17A2H version 6 Gross Primary Production product (NASA LP DAAC, 2017) from 2000 to 2010.



# 1. SOC potentiel de sequestration using digital soil mapping



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

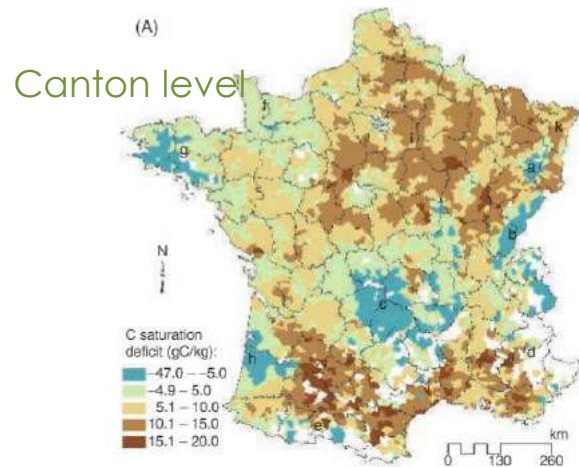


- **Hassink's (1997) equation** (on temperate soils)

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

$$SOC_{seq\_pot} = SOC_{sat} - SOC_{\text{FineFraction}}$$

# 1. SOC potentiel de sequestration using digital soil mapping



*Angers et al. (2011)*

	Area <sub>sat</sub> (km <sup>2</sup> )	Area <sub>unsat</sub> (km <sup>2</sup> )	C <sub>seq</sub> (t ha <sup>-1</sup> )	C <sub>seq-0-10</sub> (Mt)	C <sub>seq-A</sub> (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.

# 1. SOC potentiel de sequestration using digital soil mapping



## French Soil Monitoring Network (RMQS)

2092 sampling sites (16 km grid sampling)

0-30 and 30-50 cm

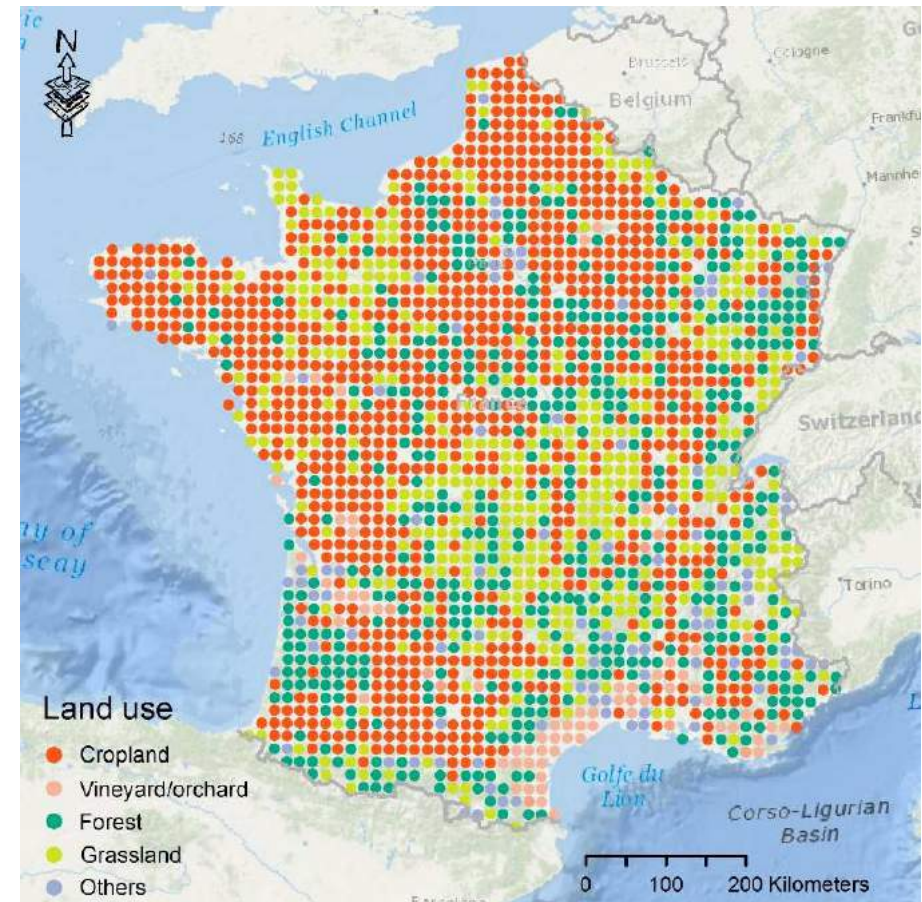
SOC

Bulk density

Coarse elements (gravel content)

Soil particle-size distribution

(0-2, 2-20, 20-50, 50-200, 200-2000  $\mu\text{m}$ )



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

# 1. SOC potentiel de sequestration 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*

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

# 1. SOC potentiel de sequestration using digital soil mapping



## ❖ Mapping SOC potentiel de sequestration

### ❑ Digital Soil Mapping

$$S = f(s, c, o, r, p, a, n) + \varepsilon$$

(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

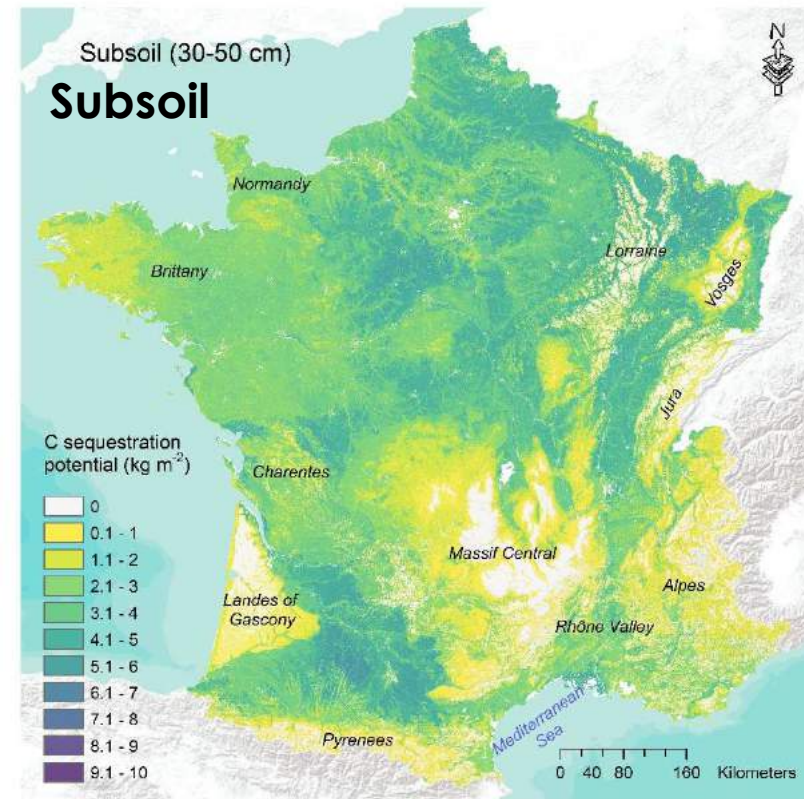
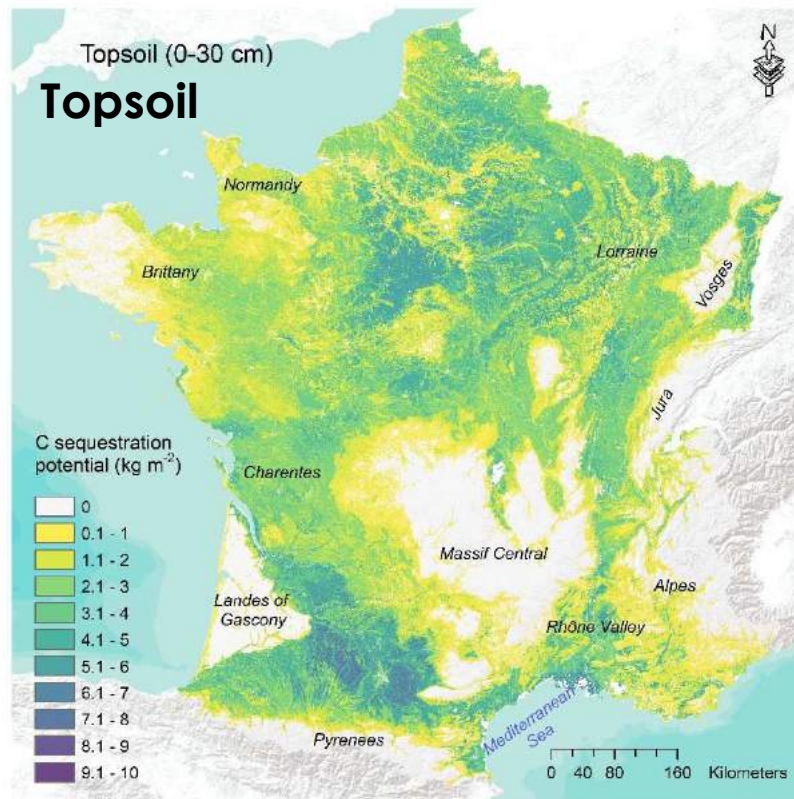
Covariates	Scorpan factors	Resolution/scale
Precipitation	Climate	1000 m
Temperature	Climate	1000 m
NPP	Organisms	1000 m
Corine Land cover	Organisms	250 m
Soil type	Soil	1:1000000
Erosion rates	Soil	1:1000000
Parent material	Parent material	1:1000000
Elevation	Relief	90 m
Aspect	Relief	90 m
Slope	Relief	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 potentiel de sequestration in France. Sci. Tot. Env.

# 1. SOC potentiel de sequestration using digital soil mapping



## □ Mapping SOC potentiel de sequestration



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

# 1. SOC potentiel de sequestration using digital soil mapping



## □ SOC potentiel de sequestration stocks (Mt)

Land cover	Topsoil 0-30cm	Subsoil 30-50 cm	Area km <sup>2</sup>
Arable land	<b>695 (69%)</b>	<b>793 (58%)</b>	<b>225,519 (43%)</b>
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 potentiel de sequestration in France. Sci. Tot. Env.