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# A model-based assessment of the soil C storage potential at the national scale: A case study from France

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## Objectives

- To assess and map the potential for additional carbon storage in agricultural soils in mainland France following the implementation of soil C storing practices
- To assess their cost
- To propose an optimal cost-efficient strategy for additional soil C storage at the national scale



# Method

Nine soil C storing practices were selected, based on a literature review

- no-tillage
- expansion of cover crops (longer and more frequent cover crops)
- new C inputs (not already spread on agricultural soils under current management practices)
- expansion of temporary grasslands (instead of silage maize)
- agroforestry
- hedges
- moderate intensification of extensive grasslands (+50kgN/ha)
- animal grazing instead of mowing
- grass cover of vineyard

For each selected practice, its potential applicability was calculated considering technical constraints (ex no reduced tillage for sugar beet, no cover crop for intercrop period < 2 months, no agroforestry if soil depth < 1m or plot size < 1ha...)

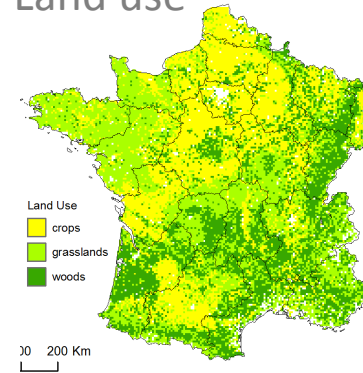
# Method

The additional C storage following the implementation of C storing practices was assessed using a modelling approach at a fine spatial-scale resolution ( $\approx 1 \text{ km}^2$ )

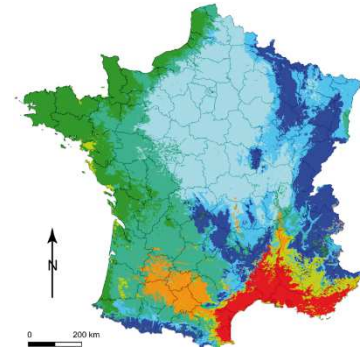
Each grid cell was characterized by its:

- dominant land-use
- local climate
- dominant soil type
- dominant cropping system (crop rotation and current farming practices)
- initial soil C stock value

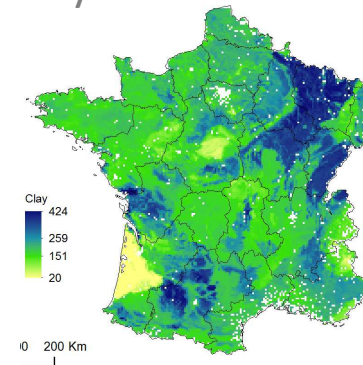
Land use



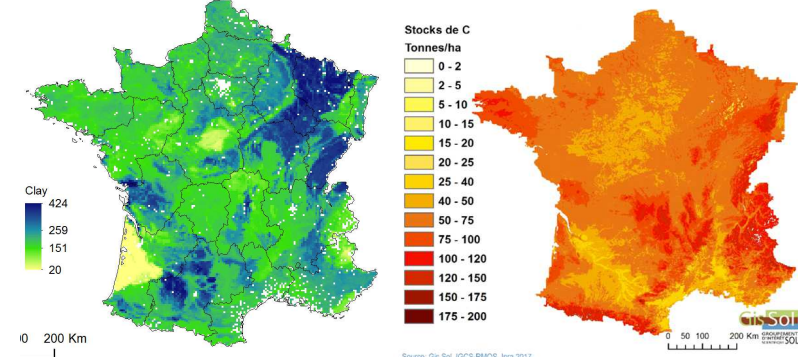
Climate



Clay content



Initial soil C stock value

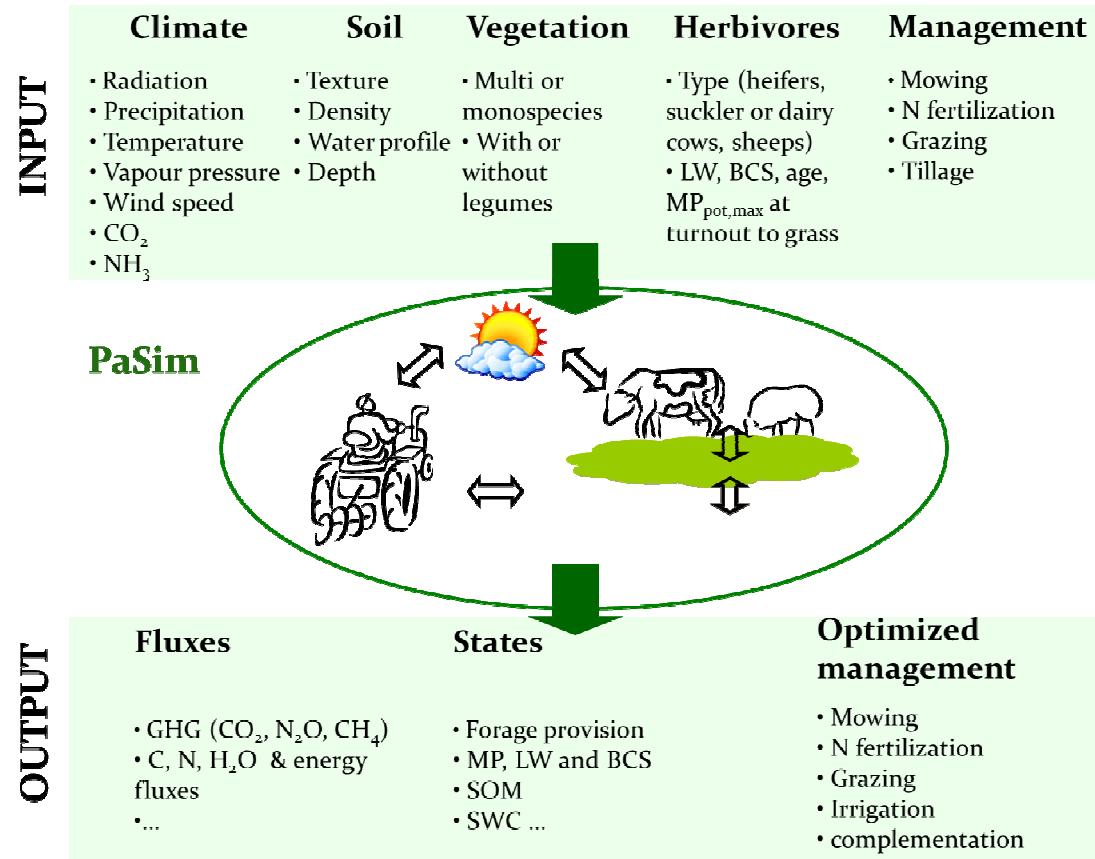


# Method

Two models were used for simulations

- STICS for arable crops
- PaSim for permanent grasslands

Both models include an explicit representation of the C cycle



# Method

For each grid cell, changes in soil C stock were simulated for a period of 30 years

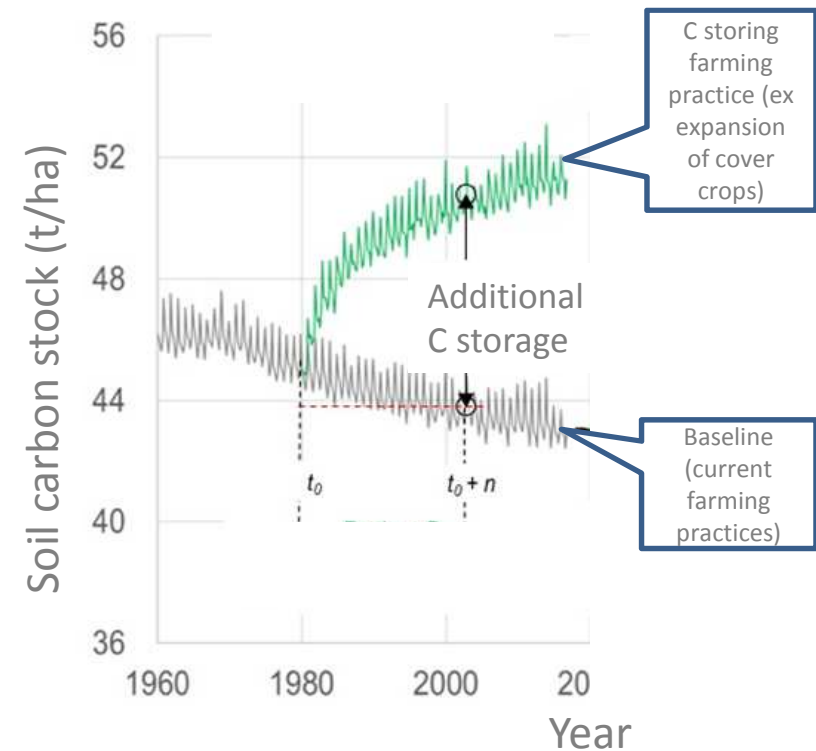
- under current management practices (= baseline)
- under C storing management practices (ex expansion of cover crops)

The additional C storage was calculated as the difference between the simulated soil C stock under C storing practices and the simulated soil C stock under current management practices

Simulations were performed under current climatic conditions

Simulations were performed for the 0-30cm horizon, and then extrapolated to the whole soil profile

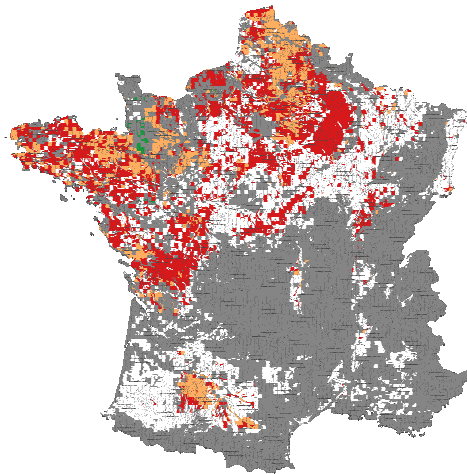
For each C storing practice, a complete greenhouse gases budget was calculated



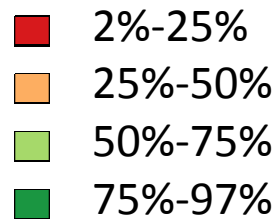
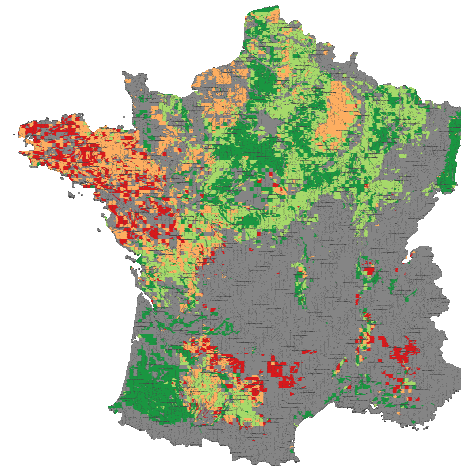
# Example of results: expansion of cover crops

## Percentage of intercrop periods with a cover crop

In the baseline (current farming practices)



In the scenario with expansion of cover crops



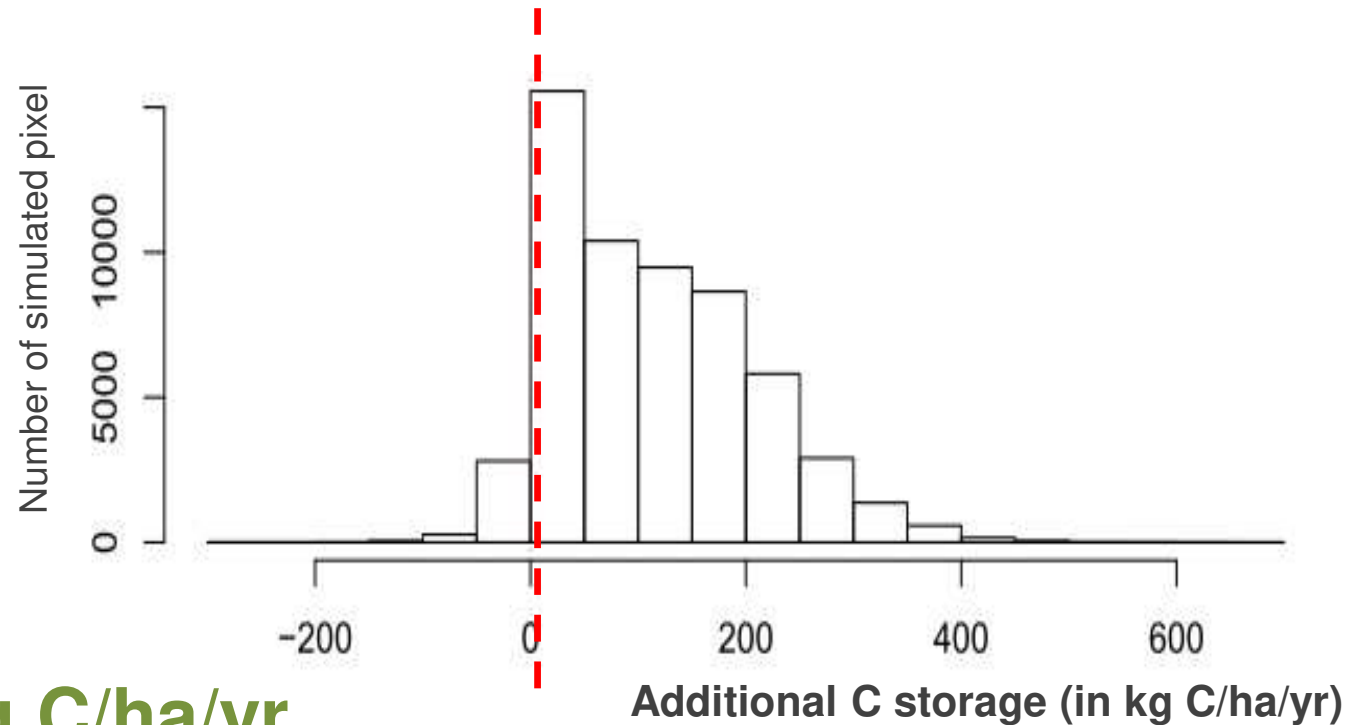
Potential applicability :  
16.6 Mha  
(96.1% of the cropland area)



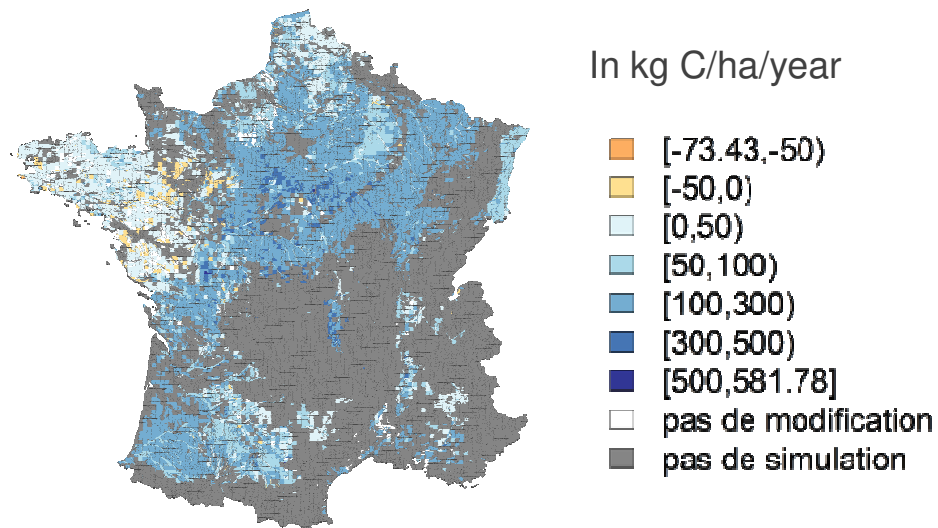
# Additional carbon storage provided by the expansion of cover crops

Average additional C storage

**+126 ± 93 kg C/ha/yr**



# Map of the additional C storage provided by the expansion of cover crops



- ❖ Less additional carbon storage provided by cover crops in the western part of France;
  - Due to crop rotations already including perennial temporary grasslands, which provide less opportunities for incorporating cover crops
- ❖ By contrast, more additional carbon storage in arable cropping systems of the Parisian Basin and South-western France

## Aggregated results for all C-storing practices

	Additional C storage 0-30 cm soil layer	Potential applicability	Potential additional C storage at the national level 0-30 cm soil layer	Relative yearly increase of soil C stocks (=949 Mt C for cropland soils in mainland France)
	Kg C/ha/an	Mha	Mt C/year	‰ /year
<b>Arable cropping systems</b>				
Expansion of cover crops	<b>+126</b>	<b>16.03</b>	<b>+2.019</b>	
No tillage	<b>+60</b>	<b>11.29</b>	<b>+0.677</b>	
New carbon inputs	<b>+61</b>	<b>4.21</b>	<b>+0.257</b>	
Expansion of temporary grasslands	<b>+114</b>	<b>6.63</b>	<b>+0.756</b>	
Agroforestry	<b>+207</b>	<b>5.33</b>	<b>+1.102</b>	
Hedges	<b>+17</b>	<b>8.83</b>	<b>+0.150</b>	
<b>Total for croplands</b>			<b>+4.960</b>	<b>+5.2 ‰</b>

## Aggregated results for all C-storing practices

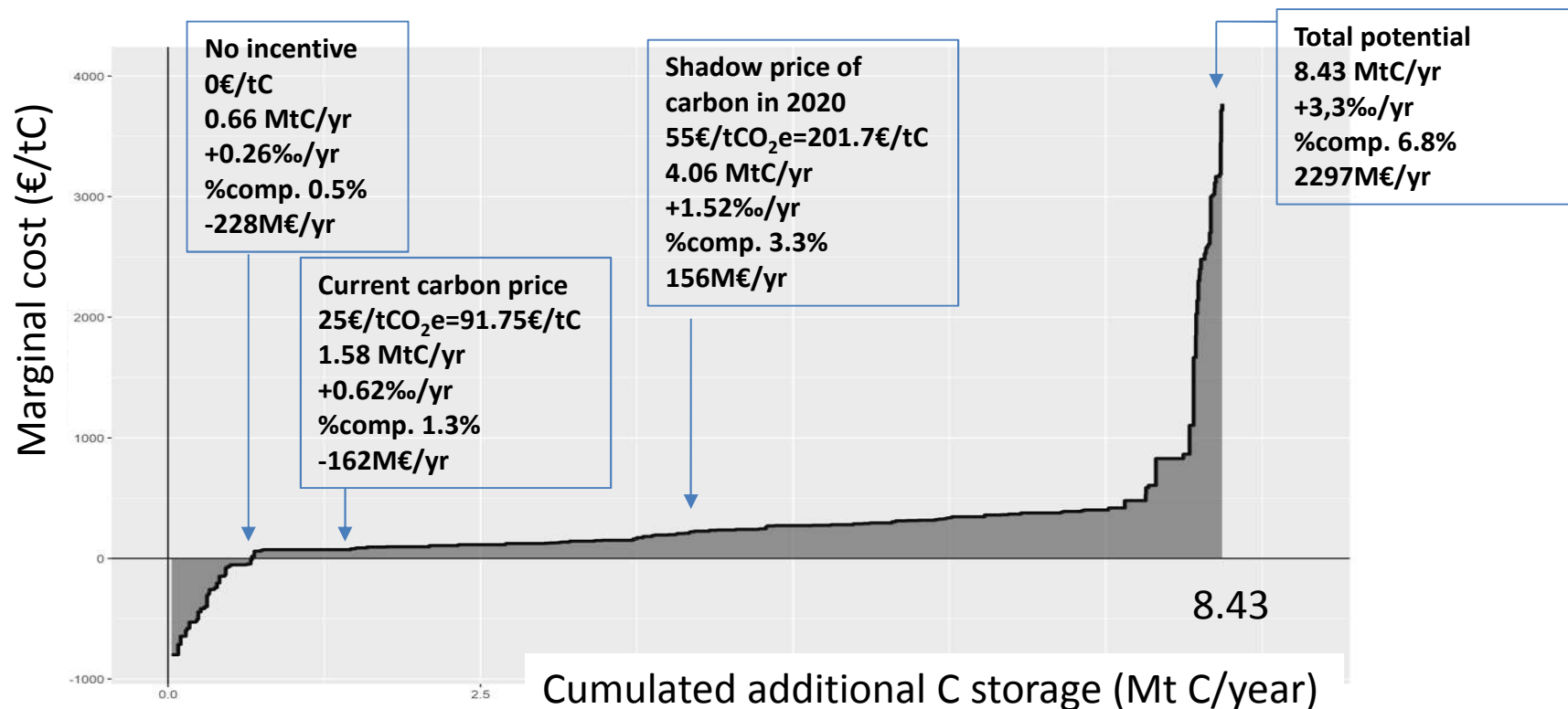
	Additional C storage Horizon 0-30 cm	Potential applicability	Potential additional C storage at the national level Horizon 0-30 cm	Relative yearly increase of the soil C stock
	Kg C/ha/year	Mha	Mt C/year	‰ /year
<b>Permanent grasslands</b>				
Moderate intensification of extensive grasslands	<b>+176</b>	<b>3.94</b>	<b>+0.694</b>	
Grazing instead of mowing	<b>+265</b>	<b>0.09</b>	<b>+0.023</b>	
<b>Total for permanent grasslands</b>			<b>+0.720</b>	<b>+0.9 ‰</b>
<b>Vineyard</b>				
Grass cover	<b>+182</b>	<b>0,56</b>	<b>+0.103</b>	
<b>Total for vineyard</b>			<b>+0.103</b>	<b>+3.7 ‰</b>
<b>Total for French agricultural soils (without forests)</b>			<b>5,78</b>	<b>+3,3 ‰</b>

- A potential for additional C storage of about 5.78 Mt C/year (in the 0-30cm soil layer)
- This represents an annual increase of +3.3‰ for agricultural soils
- Extrapolated to the whole soil profile (5.78 → 8.43 MtC = 31MtCO<sub>2</sub>e), this additional C storage would compensate
  - 6.8% of national GHG emissions (458 MtCO<sub>2</sub>e)
  - 41% of emissions from the French agricultural sector (76.7 MtCO<sub>2</sub>e)

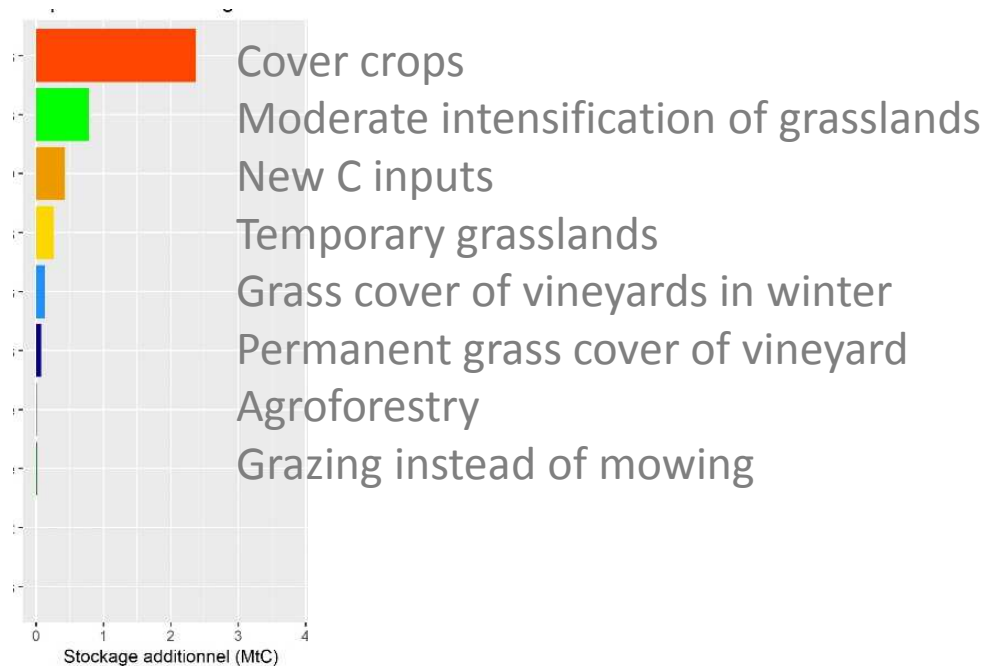
# Costs

C storing practice	Potential applicability (Mha)	Cost for farmer (€/ha/year)	Storage cost (€/tC)	Storage cost (€/tCO <sub>2</sub> )
New carbon inputs	<b>4,21</b>	<b>-52</b> (-117; -8)	<b>-494</b> (-1 192; -134)	<b>-135</b> (-325; -37)
Grass cover of vineyards permanent	<b>0,15</b>	<b>-26</b> (-27; -22)	<b>-56</b> (-44; -77)	<b>-15</b> (-21; -11)
In winter	<b>0,41</b>	<b>-15</b> (15; 15)	<b>-51</b> (-51)	<b>-14</b> (-14)
Expansion of cover crops	<b>16,03</b>	<b>39</b> (12; 147)	<b>180</b> (69; 1 104)	<b>49</b> (19; 301)
Moderate intensification of extensive grasslands	<b>3,94</b>	<b>28</b> (12; 38)	<b>130</b> (60, 1 189)	<b>35</b> (16;324)
Grazing instead of mowing	<b>0,09</b>	<b>73</b> (-85; 146)	<b>203</b> (-2 791; 518)	<b>55</b> (-761; 141)
Expansion of temporary grasslands	<b>6,63</b>	<b>91</b> (-40; 263)	<b>473</b> (-242; 1 667)	<b>129</b> (-66; 455)
Agroforestry	<b>5,33</b>	<b>118</b> (63; 179)	<b>302</b> (195; 386)	<b>82</b> (53; 105)
Hedges	<b>8,83</b>	<b>73</b> (54; 87)	<b>2 322</b> (2 013; 3 618)	<b>633</b> (549; 987)

# Marginal carbon storage cost curve



## Contributing C storage practices at the shadow price of carbon (201,7 €/tC = 55 €/tCO<sub>2</sub>e)



❖ Additional C storage : 4,06 MtC/year

❖ Total cost= 159 M€/year

❖ Contributing C storing practices :

- Cover crops : 58%
- Moderate intensification of extensive grasslands : 19%
- New C inputs : 11%
- Temporary grasslands : 6%



## Summary

- A potential for additional C storage of about 5,78 Mt C/year (in the 0-30cm soil layer)
- This represents a relative increase of +3,3‰ for agricultural soils (+ 5,2‰ if only arable soils are considered)
- This potential is mainly found in arable soils (86% of the total potential), partly because initial soil C stocks are low
- Extrapolated to the whole soil profile, this additional C storage would compensate
  - 6,8% of national GHG emissions
  - 41% of emissions from the agricultural sector
- About half of this potential is at a lower cost than the shadow price of carbon