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…)

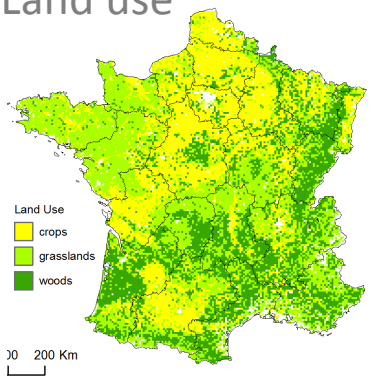
Method

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

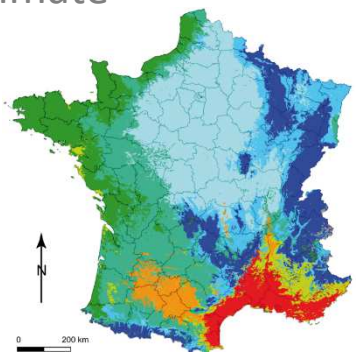
Each grid cell was characterized by its:

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

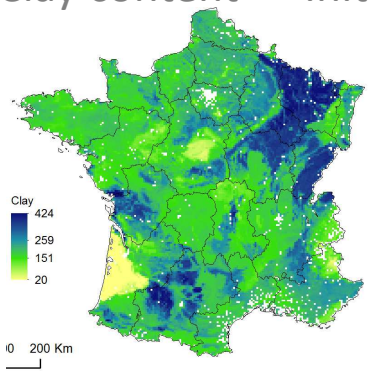
Land use



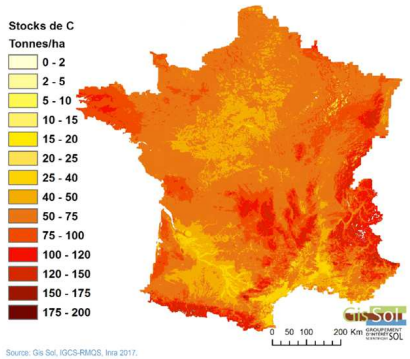
Climate



Clay content



Initial soil C stock value

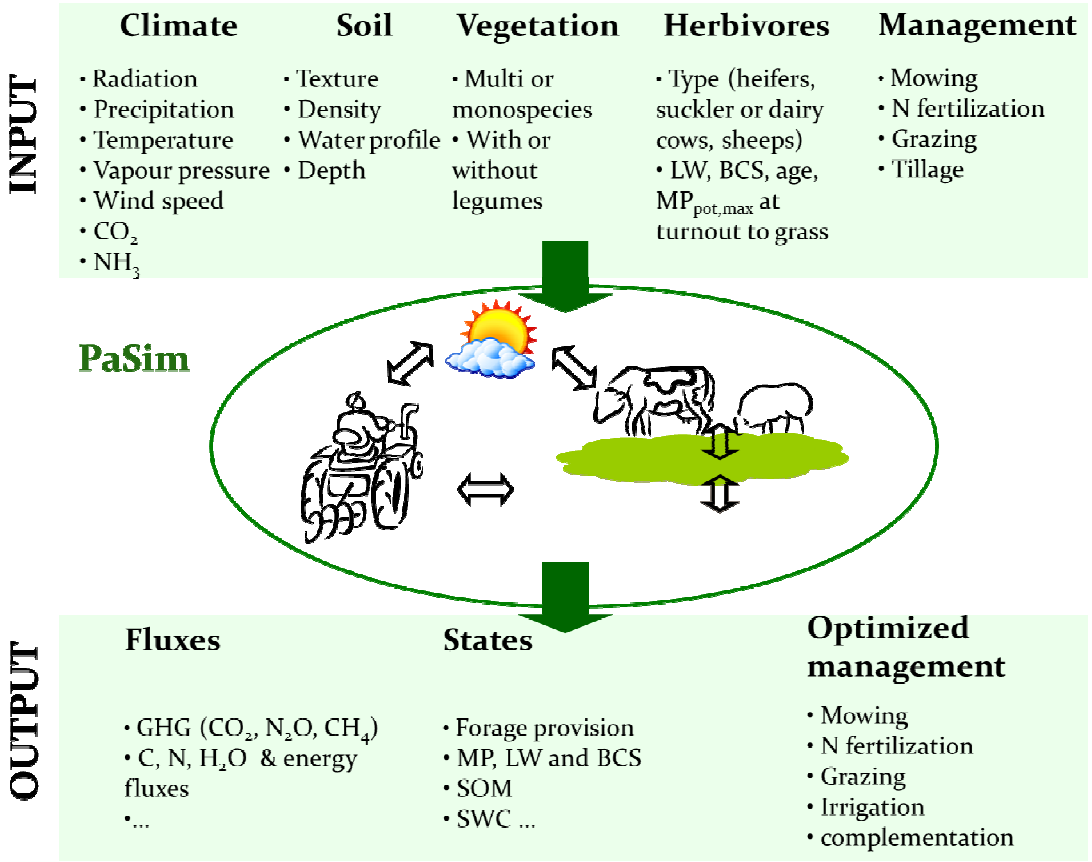


Method

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

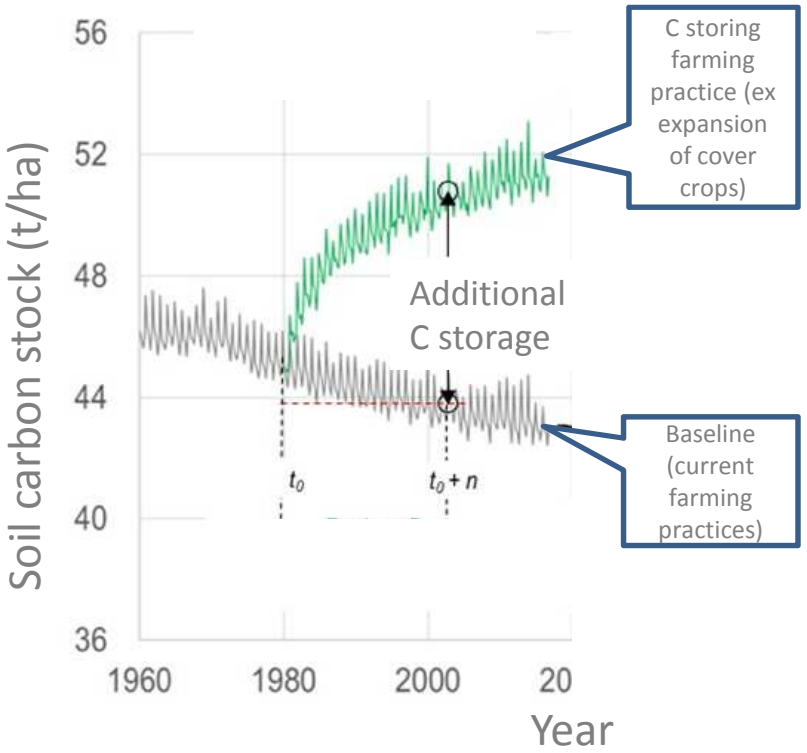
- under current management practices (= baseline)
- under C storing management practices (ex expansion of cover crops)

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

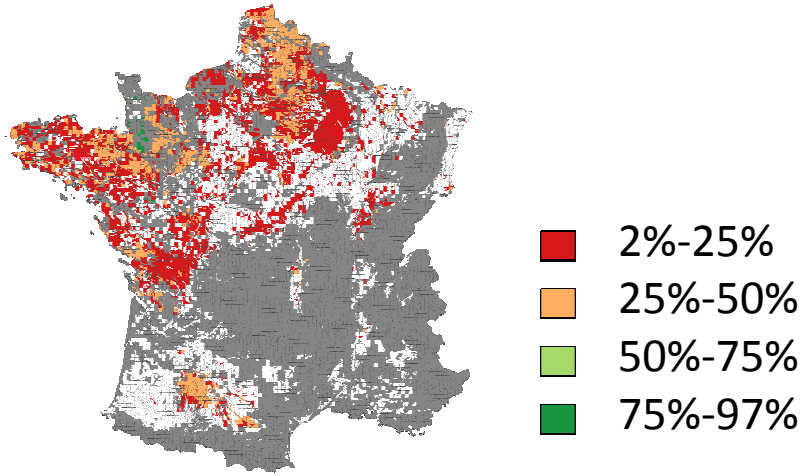
For each C storing practice, a complete greenhouse gases budget was calculated



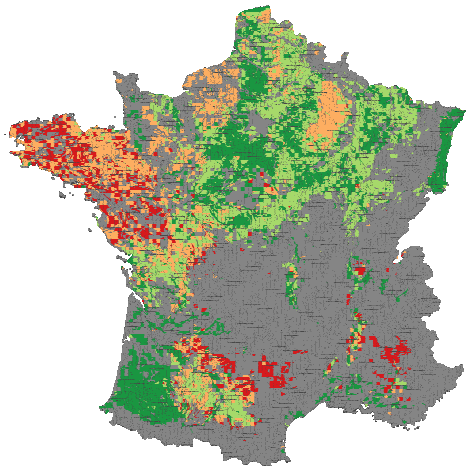
Example of results: expansion of cover crops

Percentage of intercrop periods with a cover crop

In the baseline (current farming practices)



In the scenario with expansion of cover crops

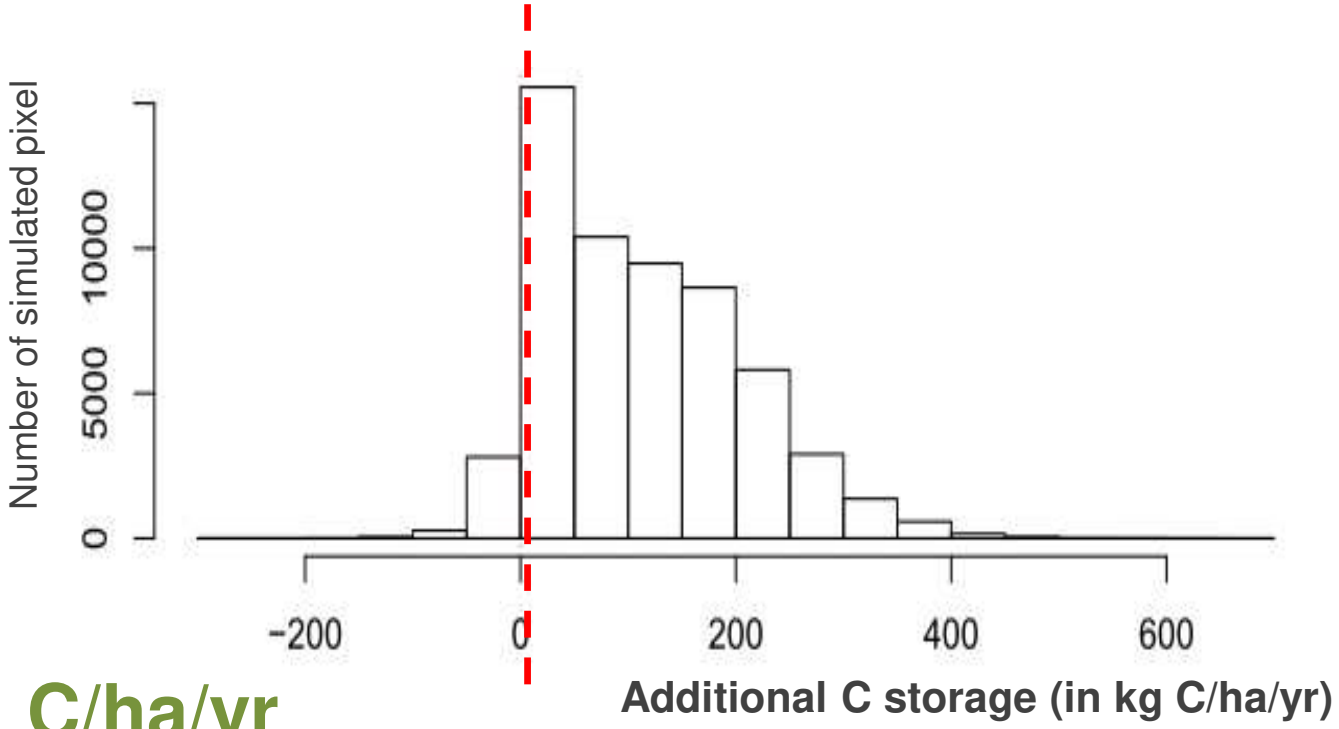


Potential applicability : 16.6 Mha (96.1% of the cropland area

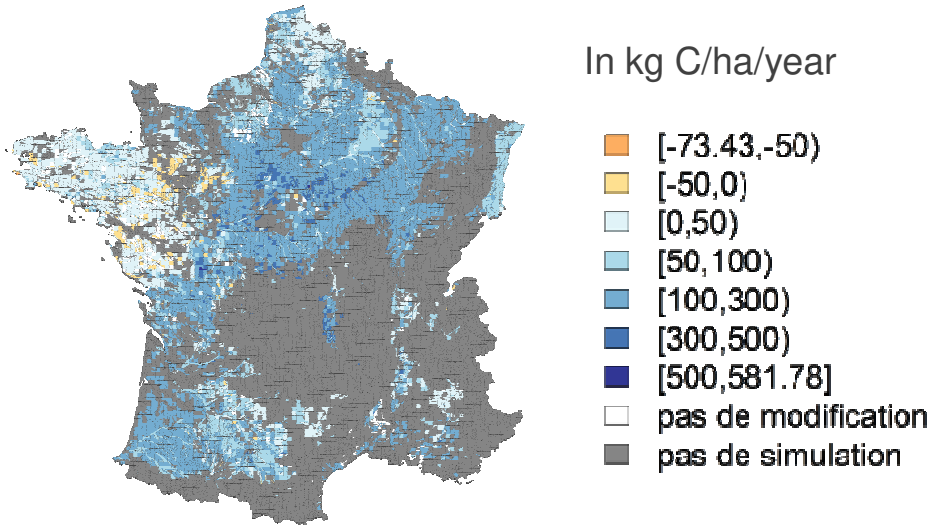
Additional carbon storage provided by the expansion of cover crops

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
Arable cropping systems				
Expansion of cover crops	+126	16.03	+2.019	
No tillage	+60	11.29	+0.677	
New carbon inputs	+61	4.21	+0.257	
Expansion of temporary grasslands	+114	6.63	+0.756	
Agroforestry	+207	5.33	+1.102	
Hedges	+17	8.83	+0.150	
Total for croplands			+4.960	+5.2 ‰

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
Permanent grasslands				
Moderate intensification of extensive grasslands	+176	3.94	+0.694	
Grazing instead of mowing	+265	0.09	+0.023	
Total for permanent grasslands			+0.720	+0.9 ‰
Vineyard				
Grass cover	+182	0,56	+0.103	
Total for vineyard			+0.103	+3.7 ‰
Total for French agricultural soils (without forests)			**5,78**	**+3,3 ‰**

- A potential for additional C storage of about 5.78 Mt C/year (in the 0-30cm soil layer)

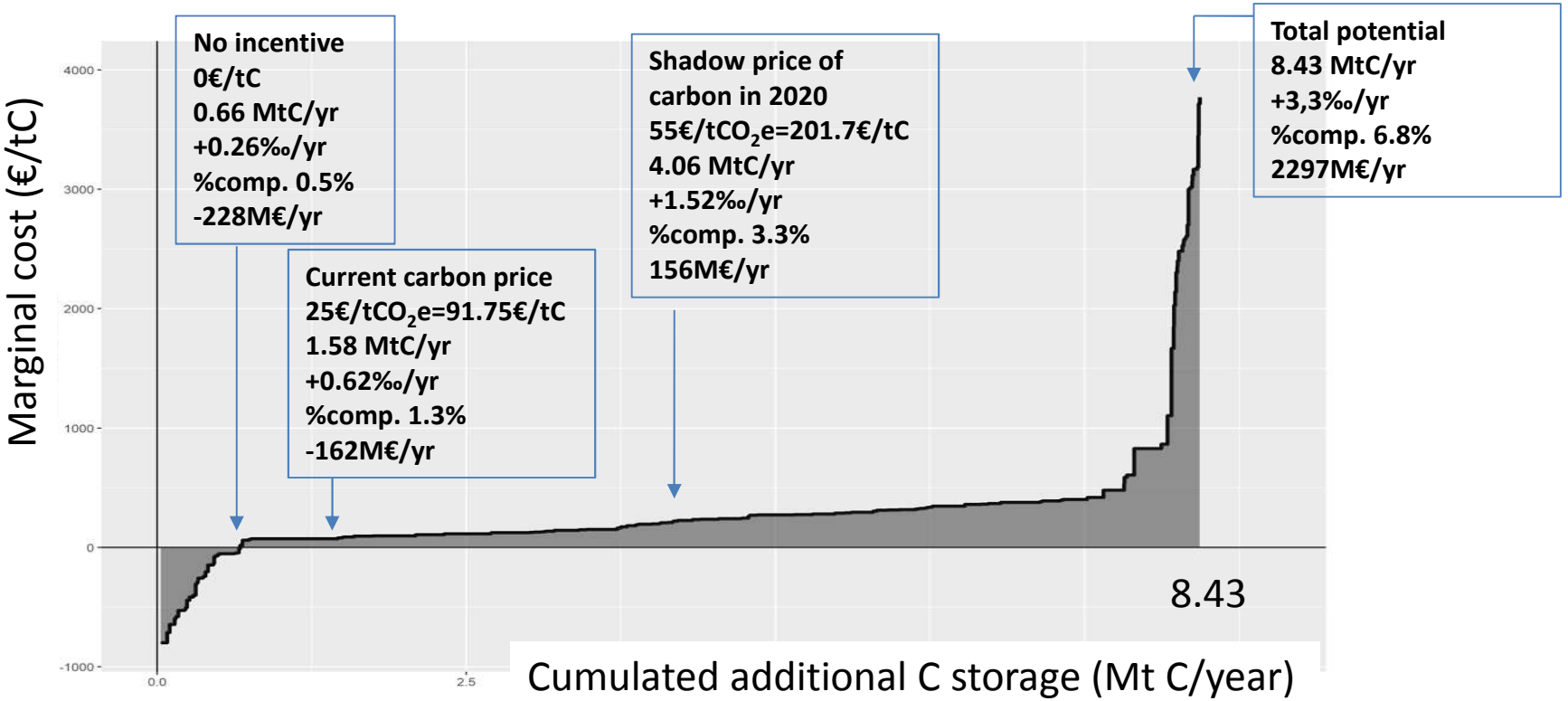
- This represents an annual increase of +3.3‰ for agricultural soils

- Extrapolated to the whole soil profile (5.78 → 8.43 MtC = 31MtCO_2e), this additional C storage would compensate
  - 6.8% of national GHG emissions (458 MtCO_2e)
  - 41% of emissions from the French agricultural sector (76.7 MtCO_2e)

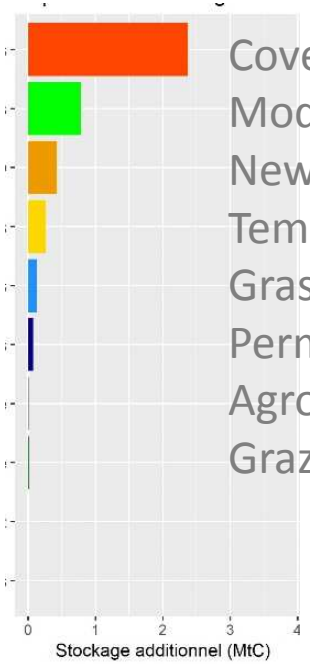
Costs

C storing practice		Potential applicability (Mha)	Cost for farmer (€/ha/year)	Storage cost (€/tC)	Storage cost (€/tCO_2)
New carbon inputs		**4,21**	**-52** (-117; -8)	**-494** (-1 192; -134)	**-135** (-325; -37)
Grass cover of vineyards	permanent	**0,15**	**-26** (-27; -22)	**-56** (-44; -77)	**-15** (-21; -11)
	In winter	**0,41**	**-15** (15; 15)	**-51** (-51)	**-14** (-14)
Expansion of cover crops		**16,03**	**39** (12; 147)	**180** (69; 1 104)	**49** (19; 301)
Moderate intensification of extensive grasslands		**3,94**	**28** (12; 38)	**130** (60, 1 189)	**35** (16;324)
Grazing instead of mowing		**0,09**	**73** (-85; 146)	**203** (-2 791; 518)	**55** (-761; 141)
Expansion of temporary grasslands		**6,63**	**91** (-40; 263)	**473** (-242; 1 667)	**129** (-66; 455)
Agroforestry		**5,33**	**118** (63; 179)	**302** (195; 386)	**82** (53; 105)
Hedges		**8,83**	**73** (54; 87)	**2 322** (2 013; 3 618)	**633** (549; 987)

Marginal carbon storage cost curve



Contributing C storage practices at the shadow price of carbon (201,7 €/tC = 55 €/tCO_2e)



Cover crops
Moderate intensification of grasslands
New C inputs
Temporary grasslands
Grass cover of vineyards in winter
Permanent grass cover of vineyard
Agroforestry
Grazing instead of mowing

- 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