Towards a more comprehensive modelling framework to quantify vertical and lateral carbon fluxes in the agricultural soils of the EU

Emanuele Lugato,

Keith Paustian, Panos Panagos,

Arwyn Jones, Pasquale Borrelli

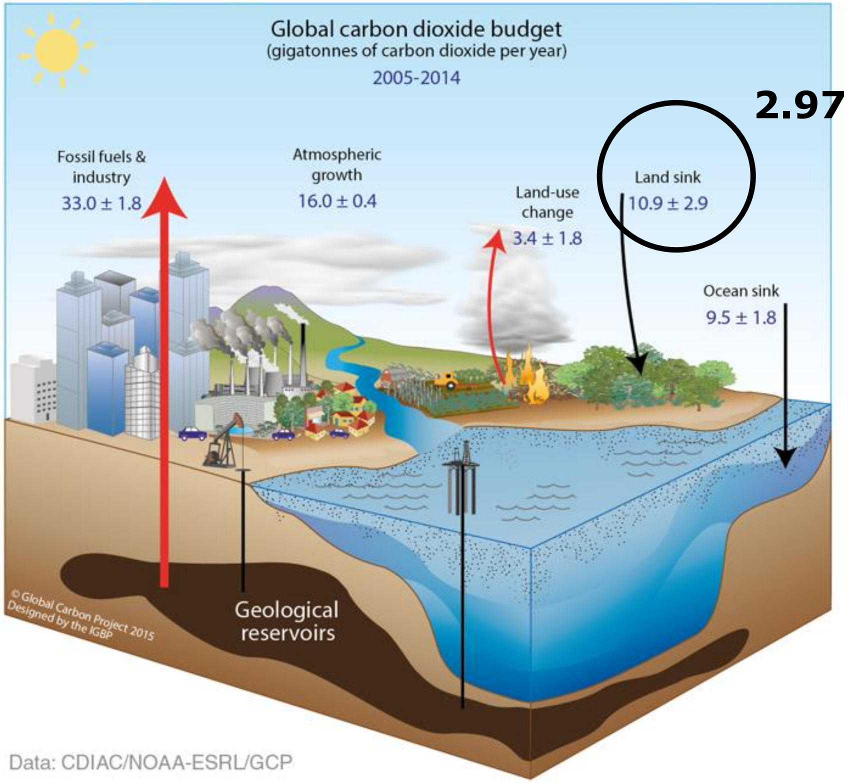
Joint Research Centre

EGU

17-22 April, 2016

Anthropogenic perturbation of the global carbon cycle

Perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2005–2014 ($GtCO_2$/yr)

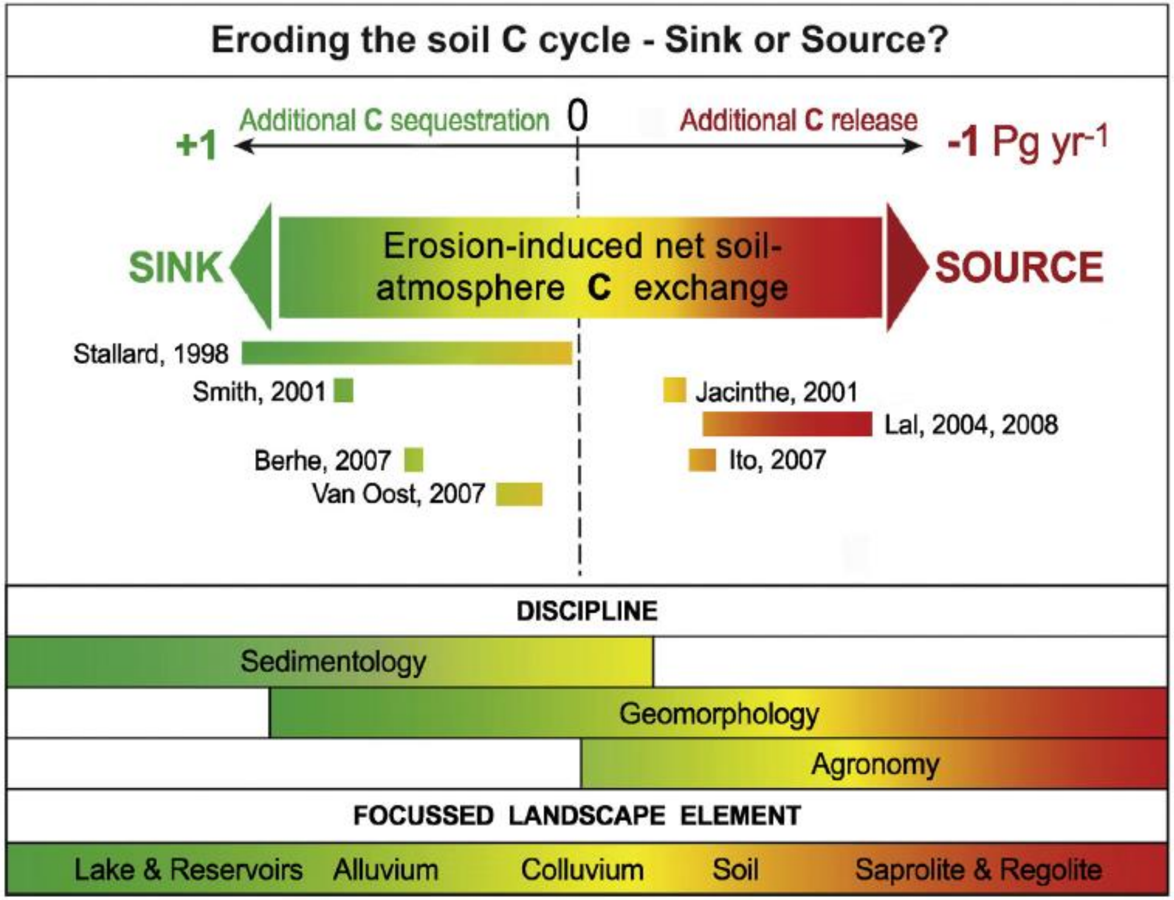


2.97 Pg of C yr^{-1}

Data: CDIAC/NOAA-ESRL/GCP

Source: CDIAC; NOAA-ESRL; Le Quéré et al 2015; Global Carbon Budget 2015

Erosion and C budget



Doetterl et al., 2016 ESR (154)

Major gaps on erosion-SOC cycle

Lacks of process understanding

C mineralization upon transportation

Mineralisation of eroded SOC during transport, as reported in different studies.

Fraction mineralised (%)	Reference
20[a]	Jacinthe and Lal (2001)
20[a]	Jacinthe et al. (2001)
20	Lal (1995)
20[a]	Lal et al. (2004b)
Near 100[b]	Schlesinger (1995)
Minor	Quinton et al. (2010)
Minor	Renwick et al. (2004)
Minor	Smith et al. (2005)
Minor	Smith et al. (2001)
<5	Van Oost et al. (2005a)
Minor	Van Oost et al. (2007)
Minor	Wang et al. (2010)

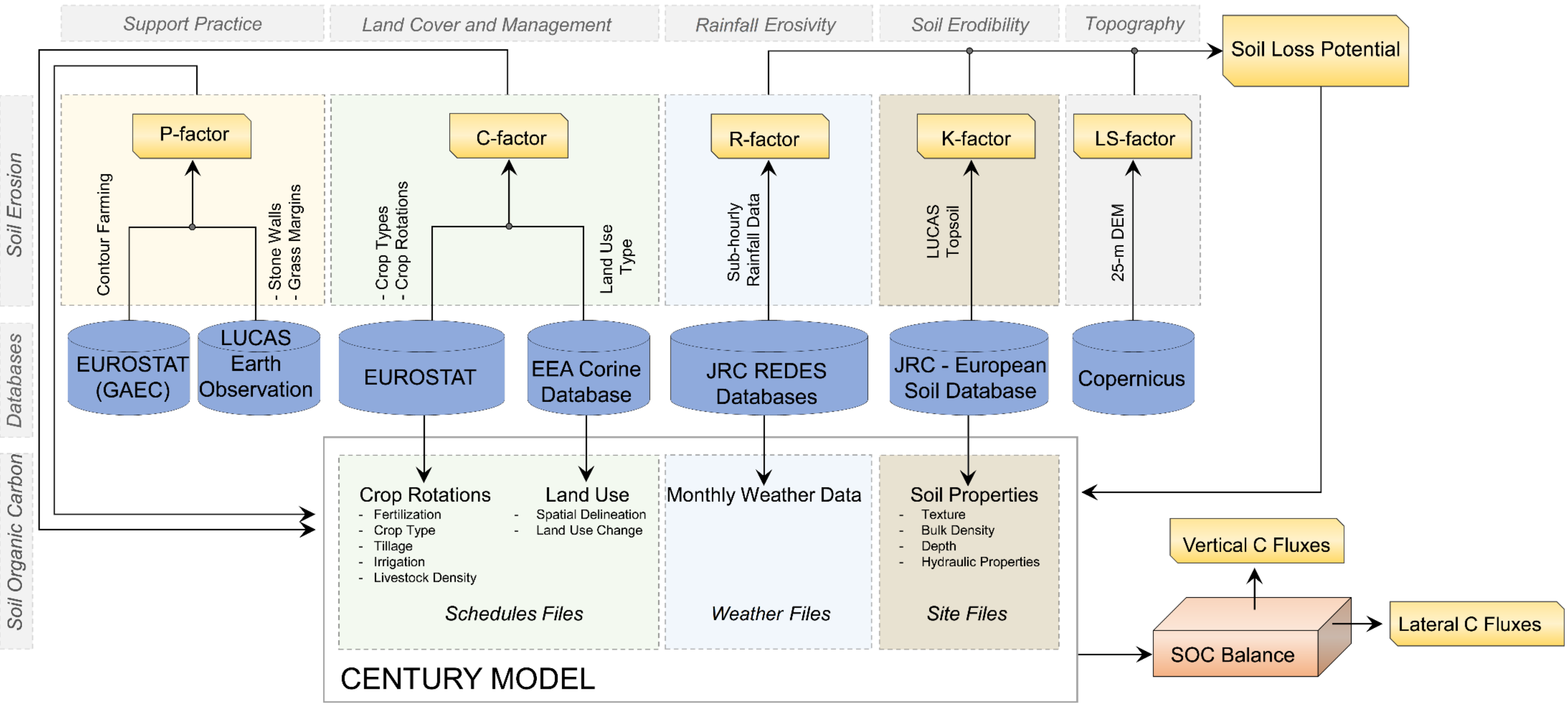
source: Kirkels et al., 2014, Geomorphology 226

Lacks of fully integrated biogeochemical-geomorphological models

Lacks of large-scale data for models parameterization

Modelling approach

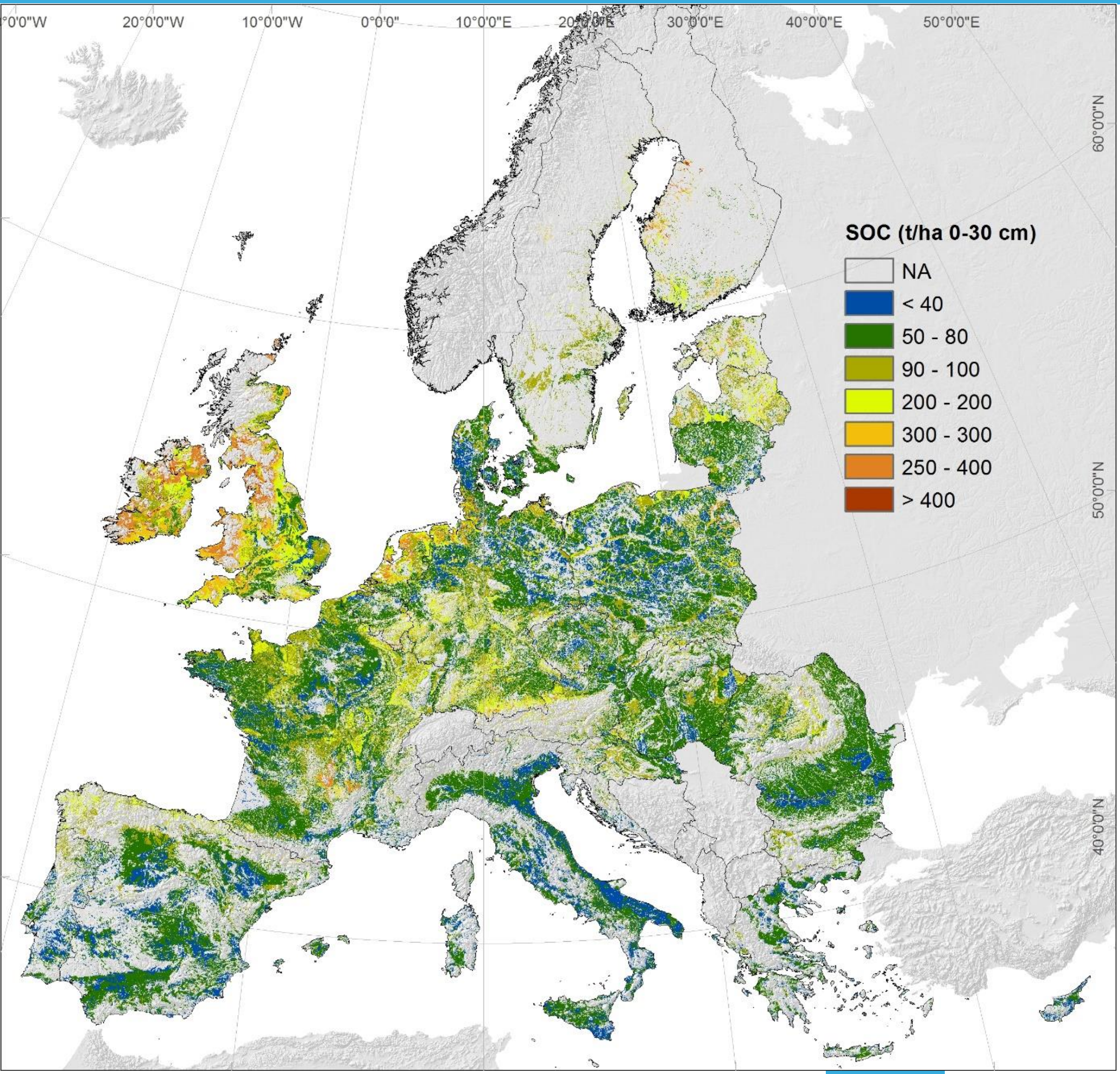
Panagos et al., 2015



Lugato et al., 2016

Modelling spatial domain

European
Commission



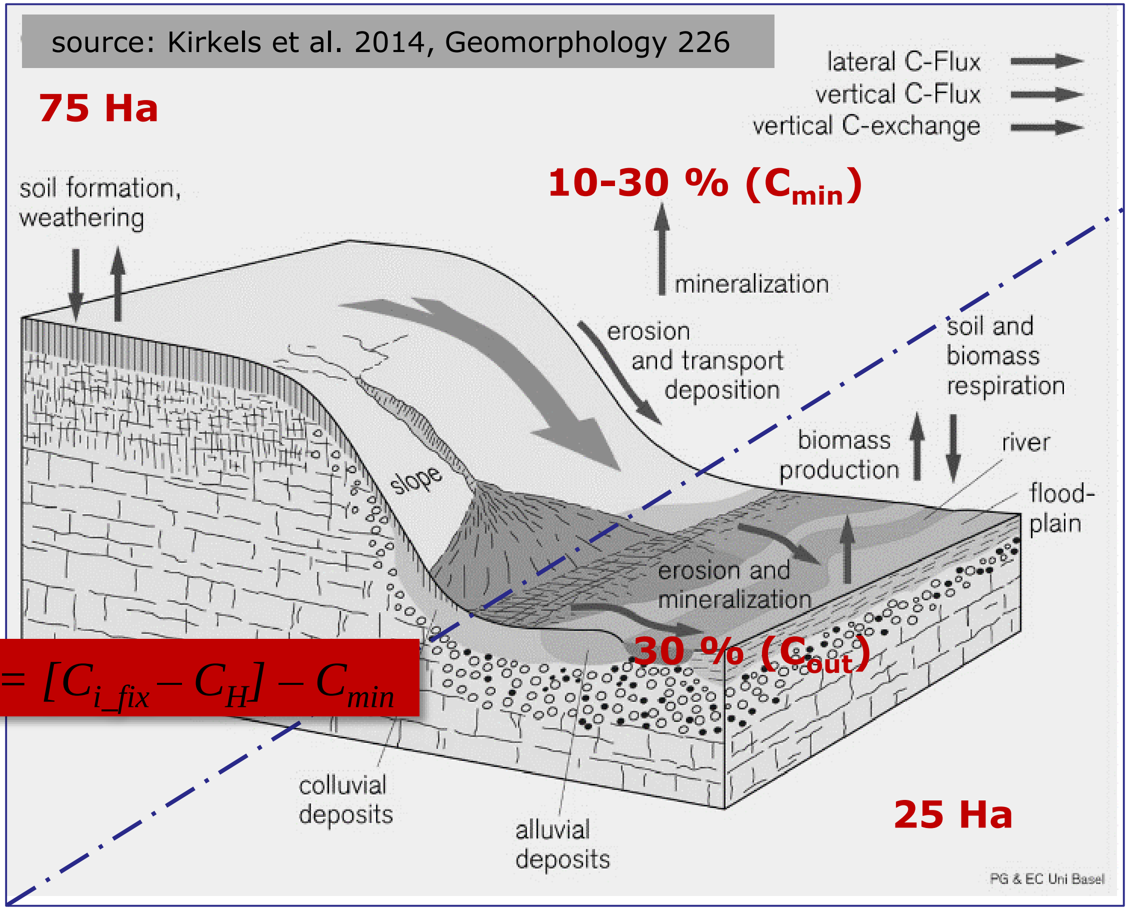
- 187 Mha agricultural soils
- 1x1 km grid cell
- 1.87M simulations
- Linux server (24 cores)

C fluxes

European Commission

$dSOC = C_{i\_fix} + \boxed{C_{i\_subsoil}} - C_H - \boxed{C_{erod}} - DOC$

Eroding area (ER)



$$fCO_2 = [C_{i\_fix} - C_H] - C_{min}$$

Depositional area (DEP)

25% of our grid cells is a depositional area, which received 70% of eroded soil [Van Oost et al., (2007)]

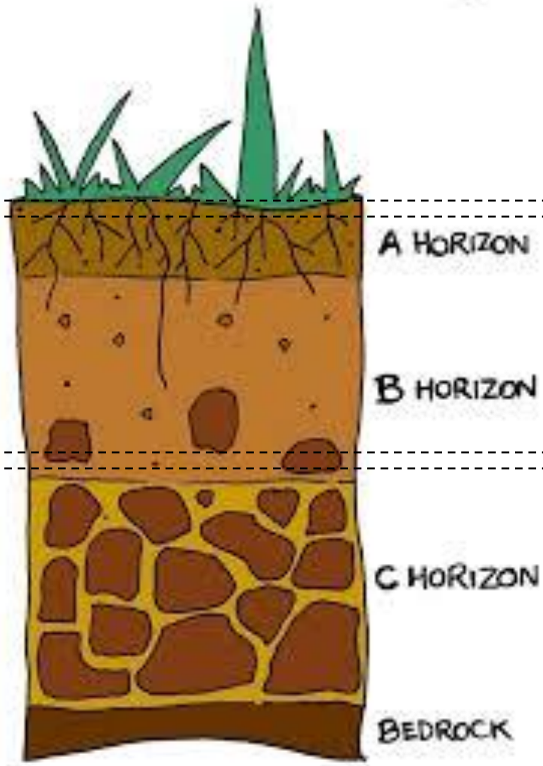
$dSOC = C_{i\_fix} + \boxed{C_{dep}} - C_H - \boxed{C_{bur}} - DOC$

Joint Research Centre

Sensitivity on model assumptions

European Commission

0-30 cm
depth



EF = 1 and 2

Sub-soil pool composition

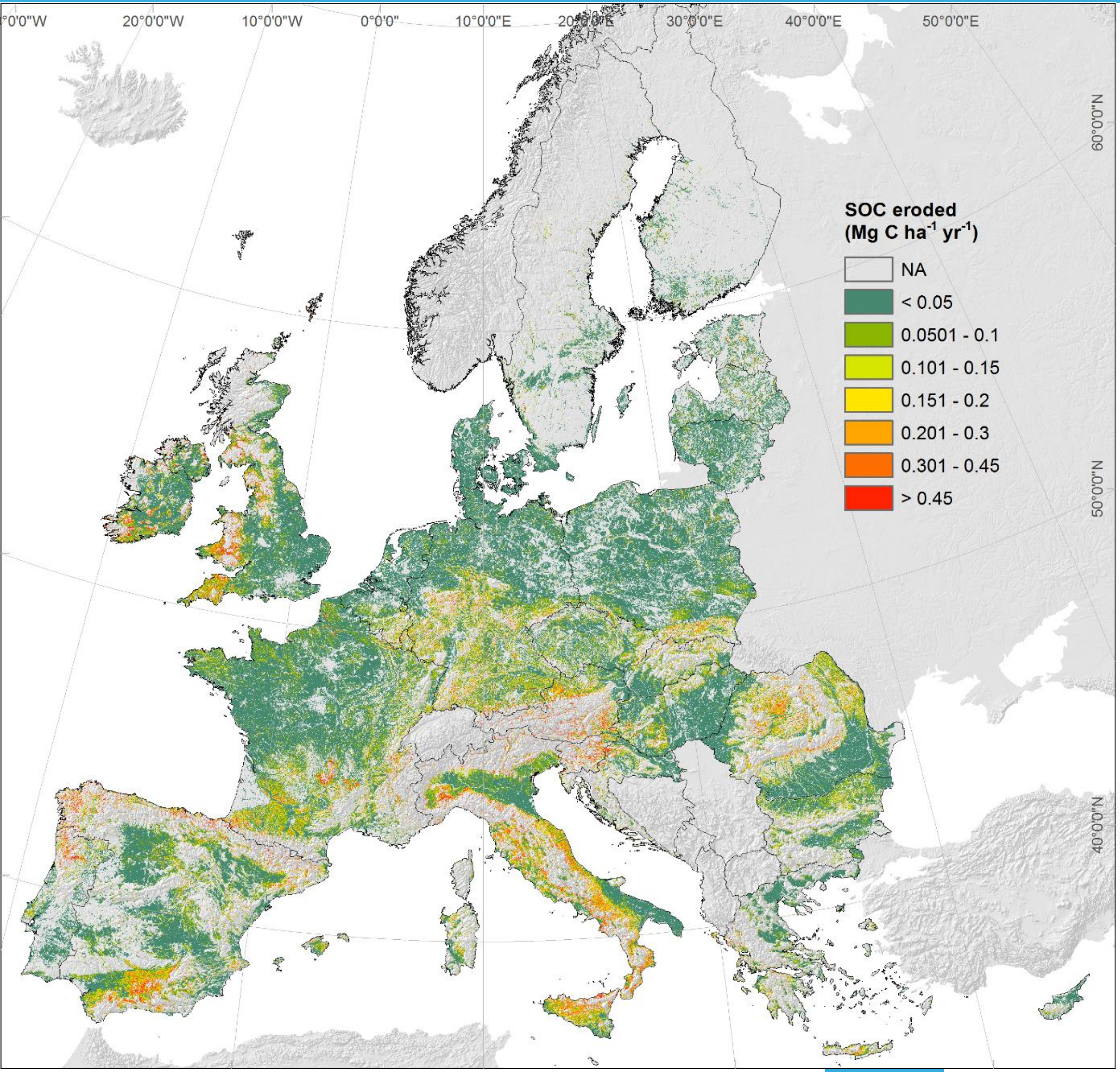
$SSL(t0) = (\underline{0.2} \times \text{Active surface}) + (\underline{0.4} \times \text{Slow surface}) + (\underline{0.8} \times \text{Passive surface})$

$SSL_i(t) = SSL_i(t-1) - SSL_i(t-1) \times FLOST(t)$

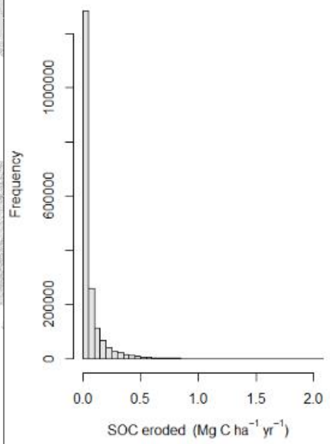
Drainage conditions on DEP areas

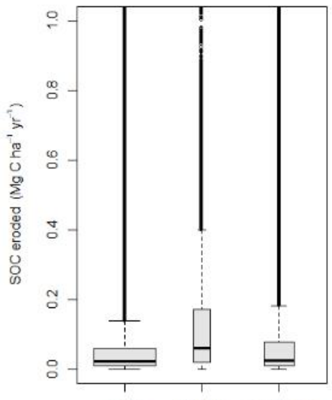
Joint Research Centre

Eroded SOC

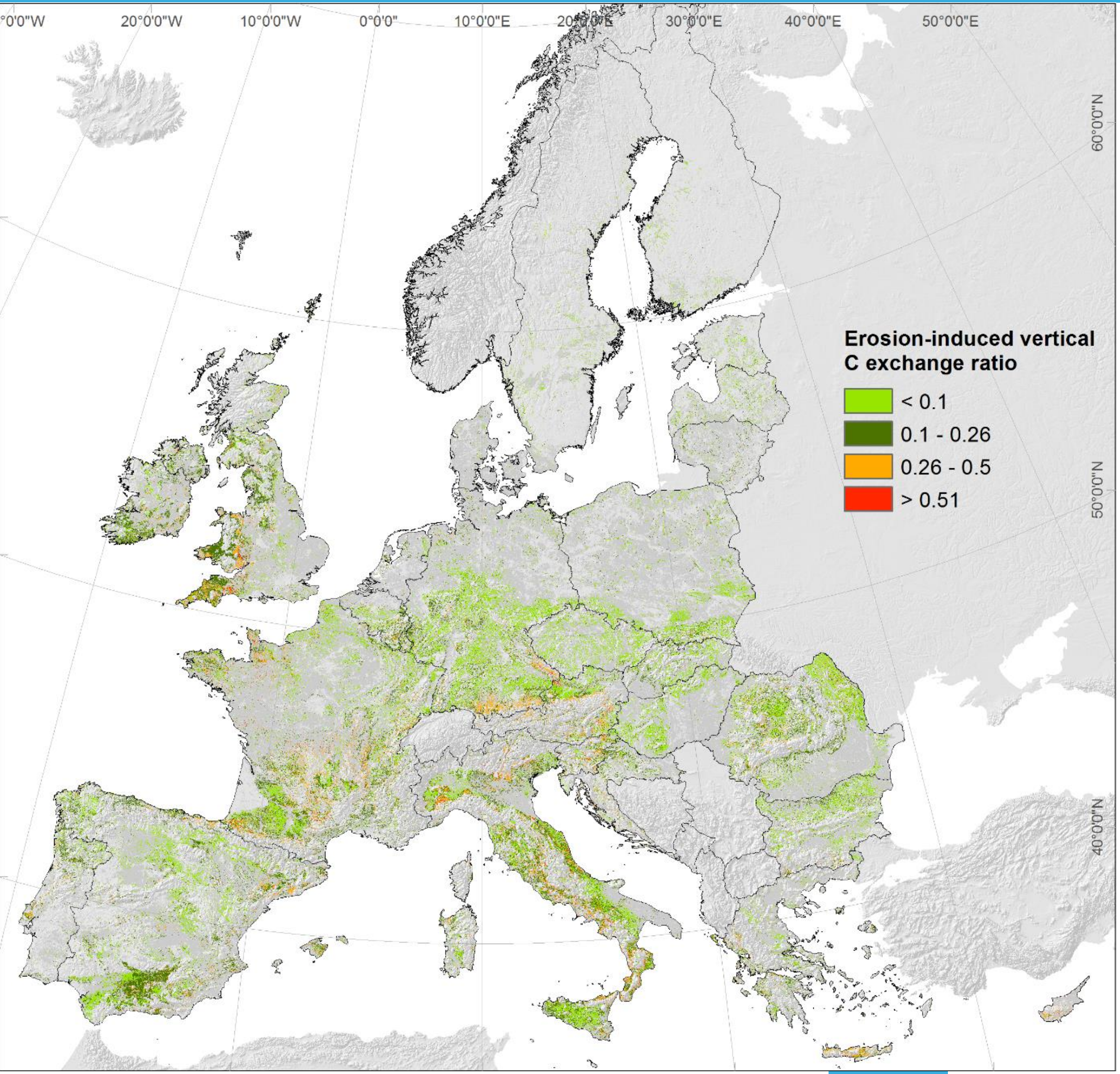


average flux
(2000-2010)





Dynamic replacement

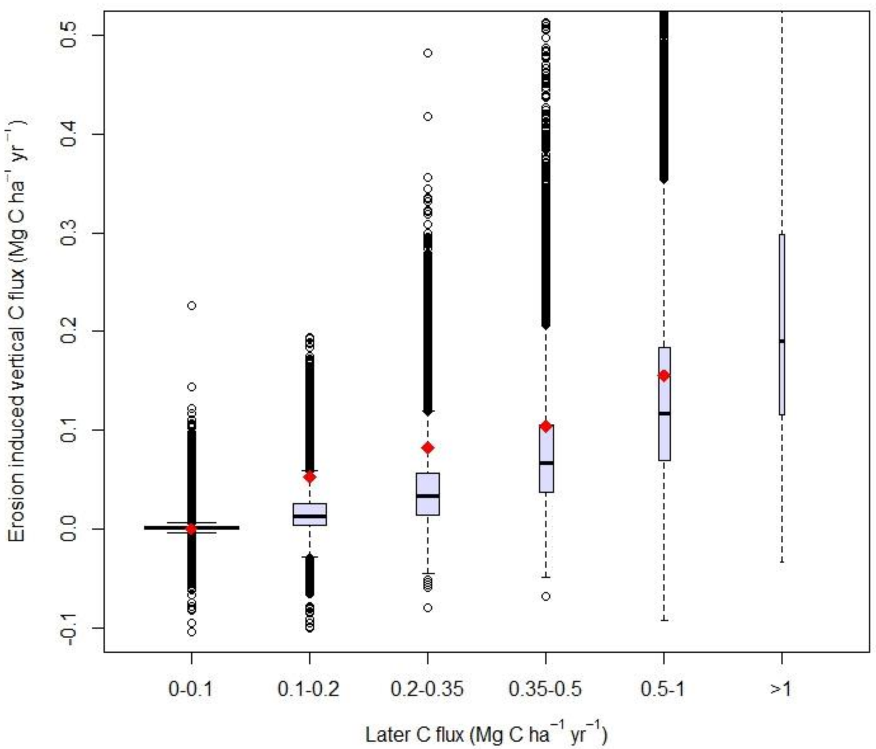


The difference of net vertical fluxes (C_{i_fix} – C_H) between eroding and non-eroding simulations, divided by the eroded C (C_{erod}).

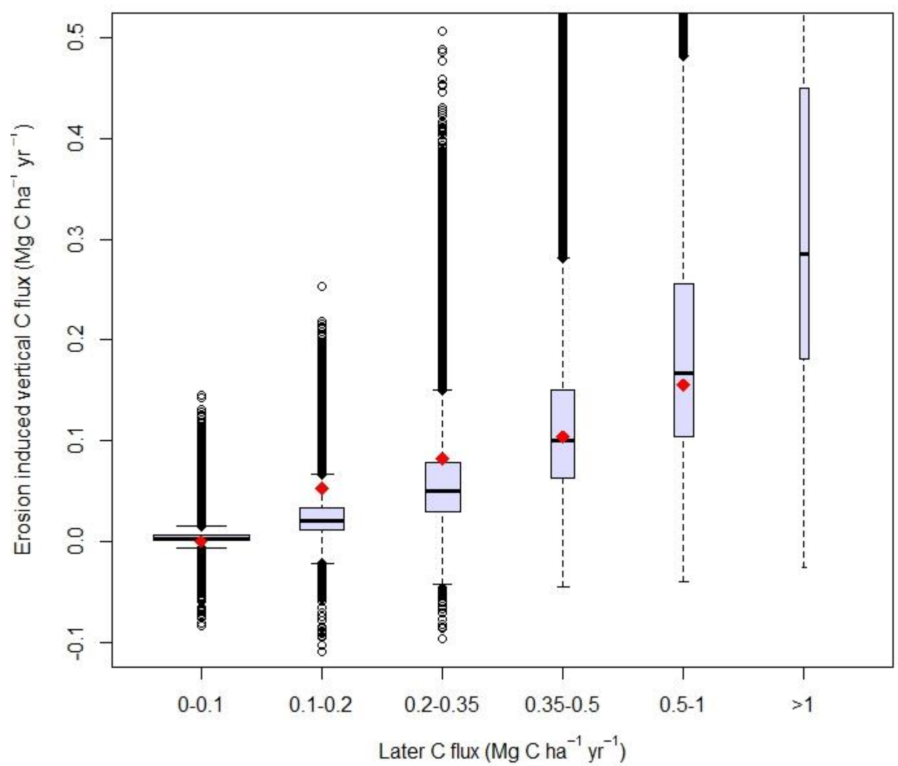
Dynamic replacement

European Commission

EF = 1



EF = 2



Boxes are modelled values

Red points are inventory-based estimations from Van Oost et al., (2007)

Joint Research Centre

SOC budget and C fluxes

Table 1 Average SOC balance (0–30 cm layer) for eroding and depositional areas in the EU and combined C fluxes

	ER	DEP	ERD	NE
C_{i_fix}	3.313	3.314 to 3.322	3.313 to 3.315	3.325
C_{i_sub}	0.040			
C_{erod}	0.068			
C_H	3.395	3.403 to 3.419	3.397 to 3.401	3.417
C_{bur}		0.154 to 0.167		
C_{dep}		0.098 to 0.125		
DOC	0.029	0.029 to 0.030	0.029 to 0.029	0.029
dSOC[eqn 1 and 2]	−0.139	−0.174 to −0.170	−0.148 to −0.147	−0.121
$C_{i\_fix} - C_H$			−0.084 to −0.086	−0.092
C_{min}			0.011 to 0.004	
fCO_2[eqn 3]			**−0.095 to −0.090**	**−0.092**
C_{out}			0.015	

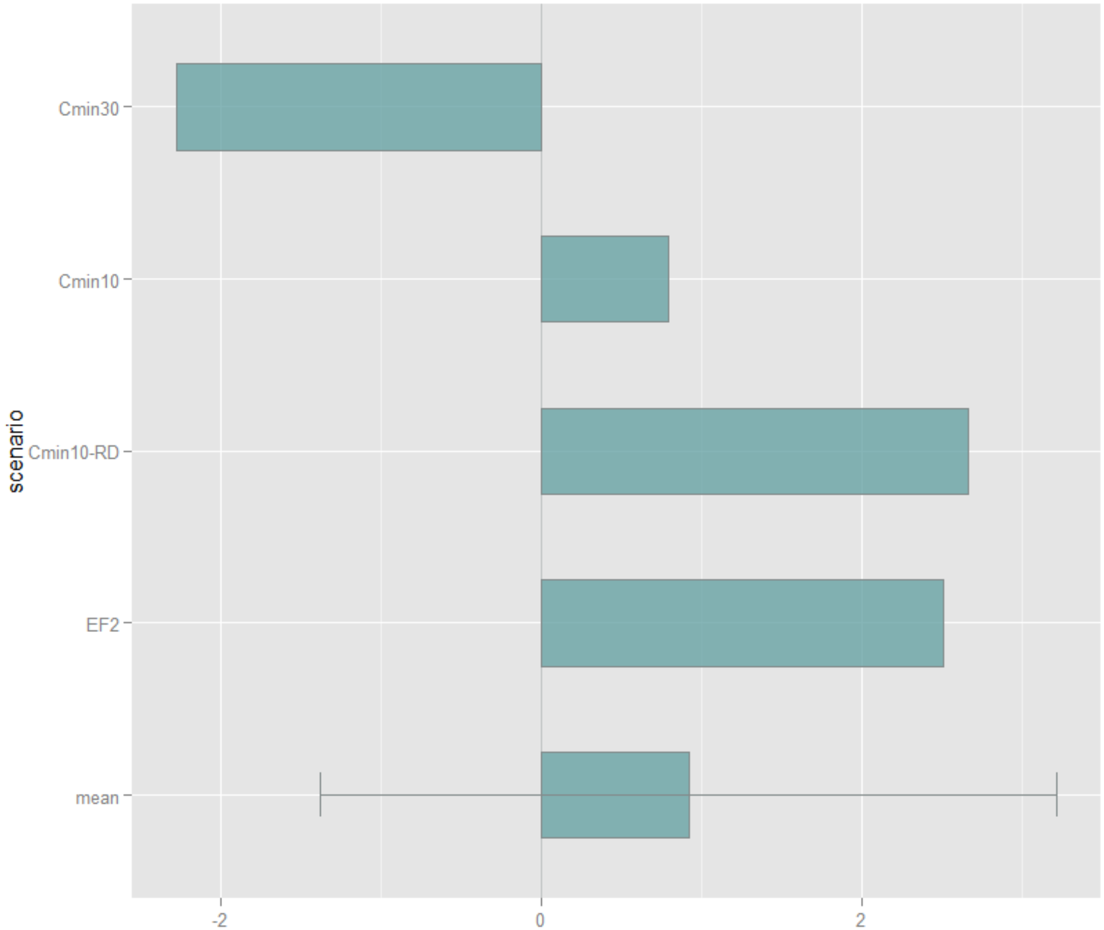
$$fCO_2 = [C_{i\_fix} - C_H] - C_{min}$$

The balance refers to the period 2000–2010 and the values are express in Mg C ha^{-1} yr^{-1}.
ERD is the weighted average fluxes of eroding (ER) and depositional (DEP) areas. NE is a simulation without erosion/deposition. The values range in DEP and ERD is calculated assuming 30 and 10% mineralization of eroded C during the transport (first and second values in the table, respectively). For consistency among equations, positive and negative fCO_2 values (in bold) represent net gain and loss of C to the atmosphere, respectively. The other C fluxes are defined in the materials and methods (equations 1,2 and 3).

Conclusions

European Commission

Erosion seems to induce a C sink in agricultural soils of the EU



Tg yr^{-1} CO_2eq.

30% mineralization

10% mineralization

Reduced drainage in DEP

EF = 2

Average

Joint Research Centre

Conclusions

European Commission

Further research is needed to:

- Develop spatial-explicit erosion/transport/deposition model working at continental
- Implement more mechanistic processes on the fate of C upon transportation (aggregate breakdown, selective transportation)
- Integrate changing environmental conditions
- Include lateral fluxes in ESM

"Essentially, all models are wrong, but some are useful.“ George E. P. Box

Joint Research Centre