Soil carbon sequestration and croplands

Dr. Jean-Francois Soussana

INRA, Paris, France

September 19, 2017
Pledges for the Paris agreement

- **128** countries include the Agriculture Forestry and Land Use sector in their pledges
  
  At least 25% of total committed mitigation
  
  [IIASA]

- A gap in emission reduction
  
  By 2030, a gap of 12 billion tons CO$_2$e prevents reaching the targeted +2°C maximum global warming threshold
Without soil carbon sequestration, staying withing 2°C cannot be achieved by the agriculture sector by 2030 (Wollenberg et al., 2016, GCB).
Soil carbon sequestration: a major option for climate and for food security

- 2-3 times more carbon in soil organic matter than in atmospheric CO$_2$ [IPCC, 2013]

- 1.4 billions metric tons (Gt C) could be stored annually in agricultural soils, equivalent to an annual storage rate of 0.4 % (rationale for the 4 per 1000 initiative) in top soil [after IPCC, 2007, 2014]

- 80 % of this potential could be reached for 100 USD per ton of CO$_2$, a price compatible with the 2°C global warming target (Smith et al., 2008, Frank et al., in press)
Even under 2° warming, land degradation lowers corn yields by end of century

Losses in soil fertility in countries with low or negative nutrient surplus

(Global EPIC model, dynamic soil, RCP 2.6)
Why Soil Carbon?
Co-benefits for adaptation, land degradation and food security


- **Annual losses of 0.3–1.0 billions tons carbon through erosion** of agricultural land (Chappell et al., 2015, NCC)

- **24-40 million metric tons additional grains** can be produced in developing countries per additional ton C per hectare stored in soils organic matter [Lal, 2006]

- **Reduced yield variability** after soil restoration leading to increased soil organic matter [Pan et al., 2009]
With soil carbon sequestration, food security is not threatened, even for a 1.5°C global warming target (Frank et al., Env. Res. Lett., 2017)

SOC, soil organic C sequestration; SOC+, including its benefits for yields
Agricultural practices for soil carbon sequestration

- Conservation tillage
- Integrated soil fertility management
- Rangeland Management
- Water management
- Agroecology
- Agroforestry
- Organic fertilizers
A 4 per 1000 SOC sequestration rate has often been exceeded in long-term arable field trials. But the rate declines with initial SOC stock.

(Minasny et al., 2016, Geoderma)
A 4 per 1000 SOC sequestration rate has often been exceeded in long-term arable field trials (over up to 50 yrs)

(Minasny et al., 2016, Geoderma)
Additional organic carbon returns to soils with 4 per 1000 compared to current baseline

Median: +0.89 tC /ha/ yr, that is +2 tDM

(RothC model, inverse mode, bias correction. IIASA, INRA)

(Lutfalla et al., EGU 2017)
Mean crop carbon cycle change during 30 yrs under 4 per 1000

(Global means, tC/ha)

Current

(Grazed, burned) 0.9
10.5 (Photosynthesis)
4.4 (Respiration)
5.8 (NPP)
3.4 (residues, manures)
52.0

2050
(Grazed, burned) 1.2
13.9 (Photosynthesis)
6.3 (Respiration)
7.6 (NPP)
4.5 (residues, manures)
58.6

A scenario adding a 1% annual increase to yield increases
Limits of soil carbon sequestration

- Adoption of SOC sequestration measures will take time,
- SOC will increase only over a finite period (30-50 yrs locally), up to the point when a new SOC equilibrium is approached,
- The additional SOC stock will need to be monitored and preserved by adapting land management practices to climate change,
- Soil phosphorus (P) and nitrogen (N) should be available (root symbioses could help) as well as organic carbon recycling
- Soil and water management need to be combined, especially in dry regions
Adoption and permanence of improved practices

Figure 3. Historical trend in the expansion of cropland area under conservation agriculture (1999-2011) and projected trends assuming the same (solid lines, 8.9%) or a reduced (dashed lines, 5%) annual relative adoption rate with permanent improved practices (black) and with (red) an average 50 years duration of the improved practices before drop-out (i.e. 1.4% annual relative drop-out rate).

(Soussana et al., STILL, submitted)
Baseline issues for SOC sequestration

Three contrasted theoretical baselines:
- A, increasing SOC baseline (e.g. > 0.4% per yr), no changes required
- B, constant SOC baseline, target a moderate increase (e.g. +0.4% / yr)
- C, declining SOC baseline, target restoration (e.g. change relative to baseline by +0.4% per yr)
Thank you for your attention....