

# Soils and Climate Change

Susan Trumbore

Max-Planck Institute for Biogeochemistry and Earth System Science,  
UC Irvine

thanks to Marion Schrumpf, MPI-BGC and EAG Schuur, Northern Arizona University



CO<sub>2</sub>

Plants

Corg +  
nutrients

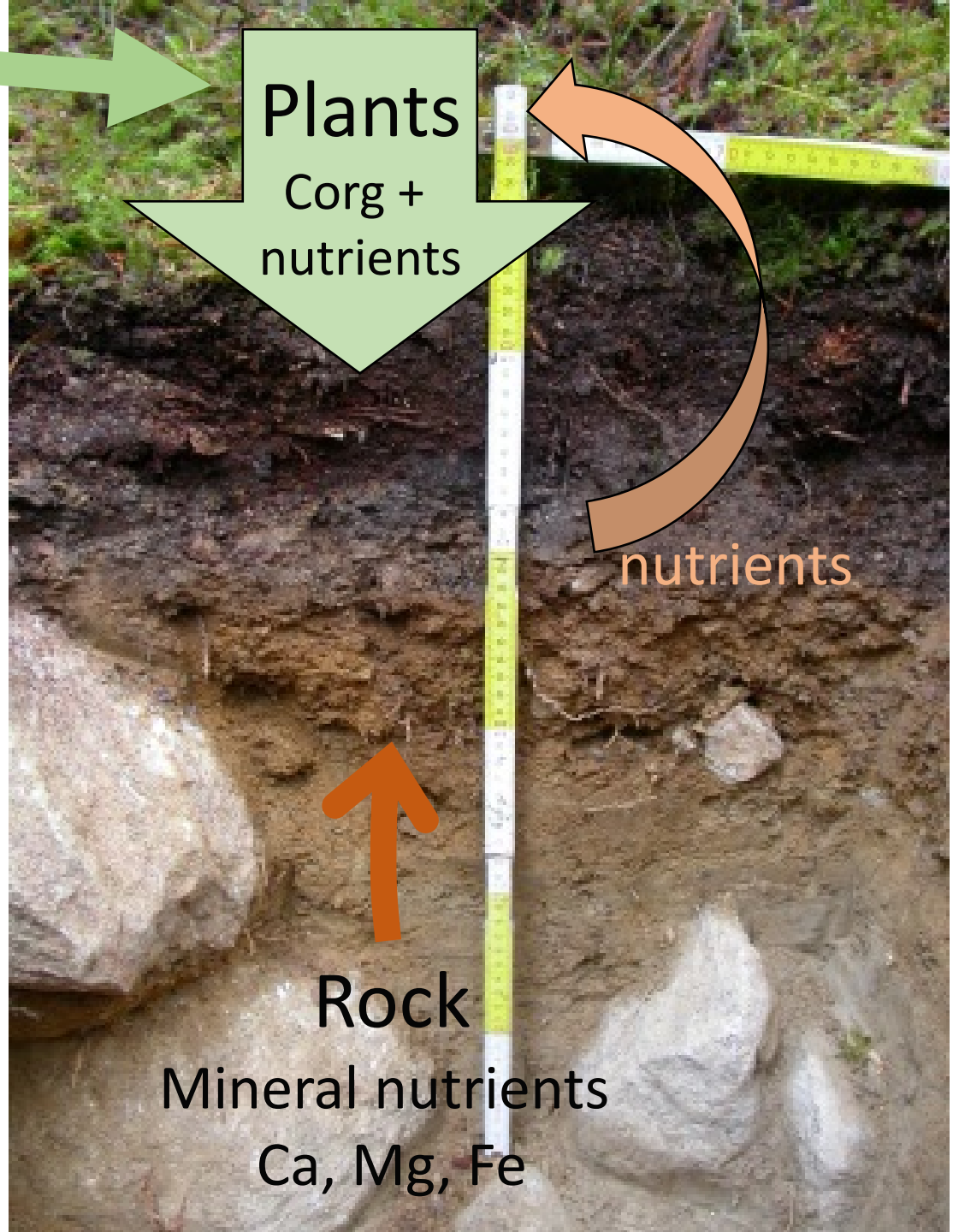
nutrients

Rock

Mineral nutrients

Ca, Mg, Fe

Soil  
develops  
where rocks  
meet air,  
water and  
biota



Decomposition  
of organic  
matter supplies  
energy and  
recycles  
nutrients

CO<sub>2</sub>

Plants

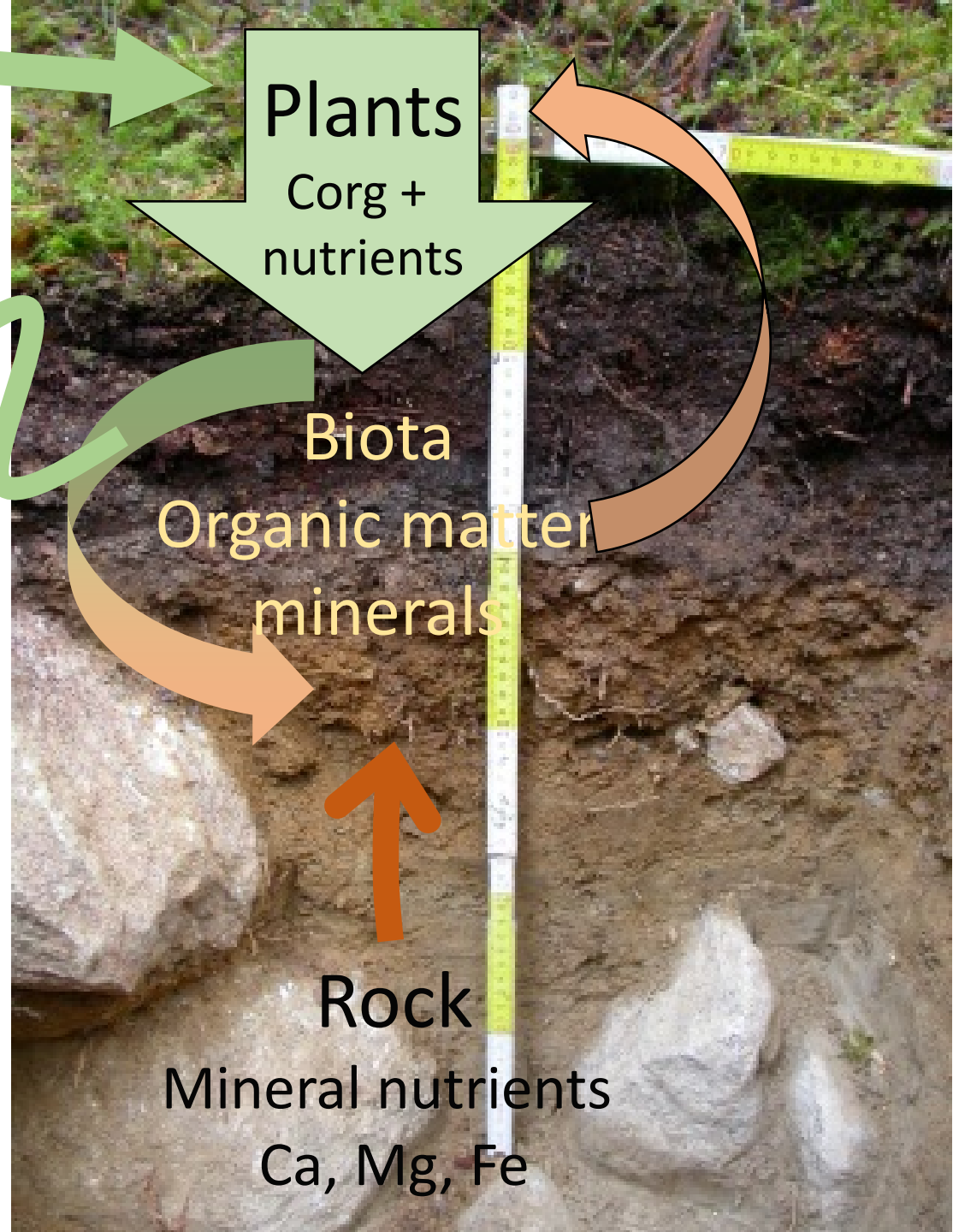
Corg +  
nutrients

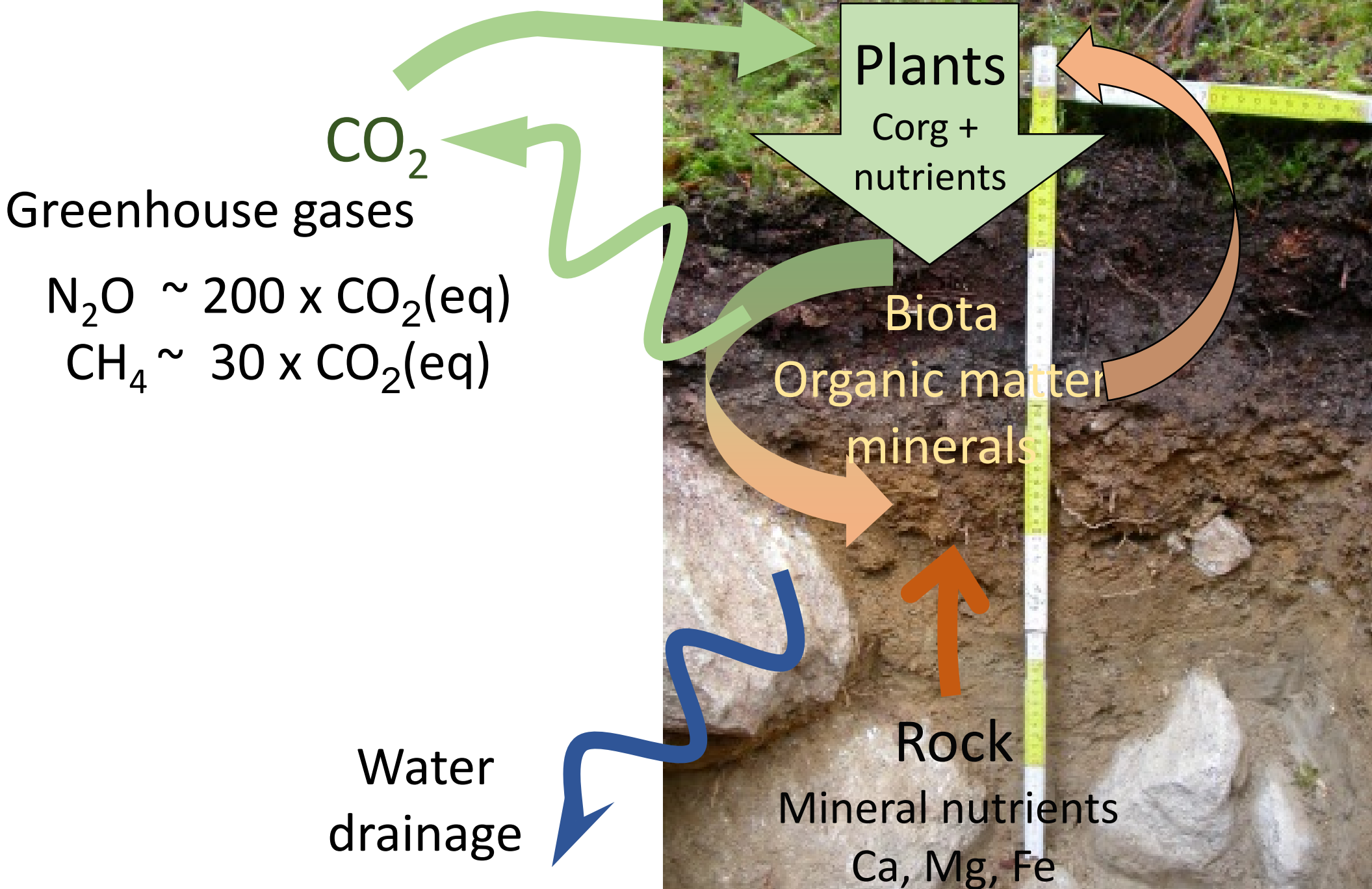
Biota

Organic matter  
minerals

Rock

Mineral nutrients  
Ca, Mg, Fe





Greenhouse gases

$N_2O \sim 200 \times CO_2(eq)$

$CH_4 \sim 30 \times CO_2(eq)$

Plants

Corg +  
nutrients

Biota

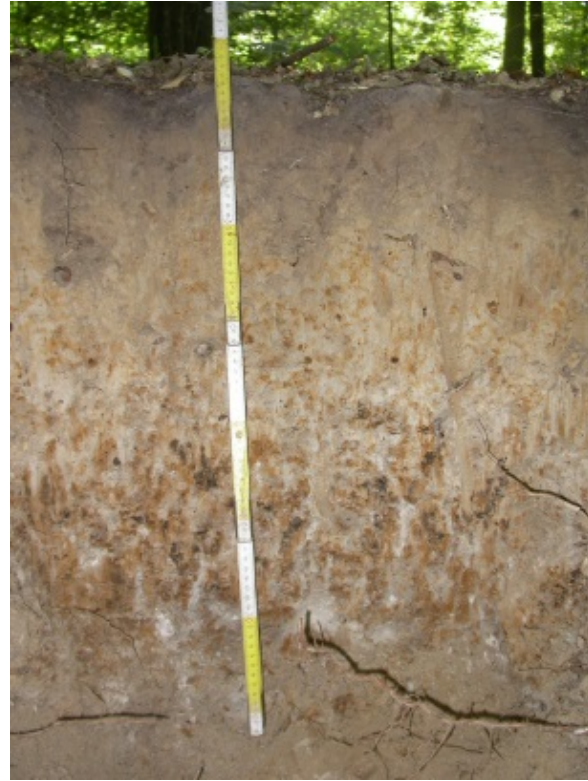
Organic matter  
minerals

Rock

Mineral nutrients  
Ca, Mg, Fe

Water  
drainage

# Properties vary with rock, plants, climate, time



Photos M. Schrumpf

**Tropical soil:** high inputs, fast decomposition, efficient recycling

**Boreal soil:** moderate inputs, slow decomposition, inefficient recycling

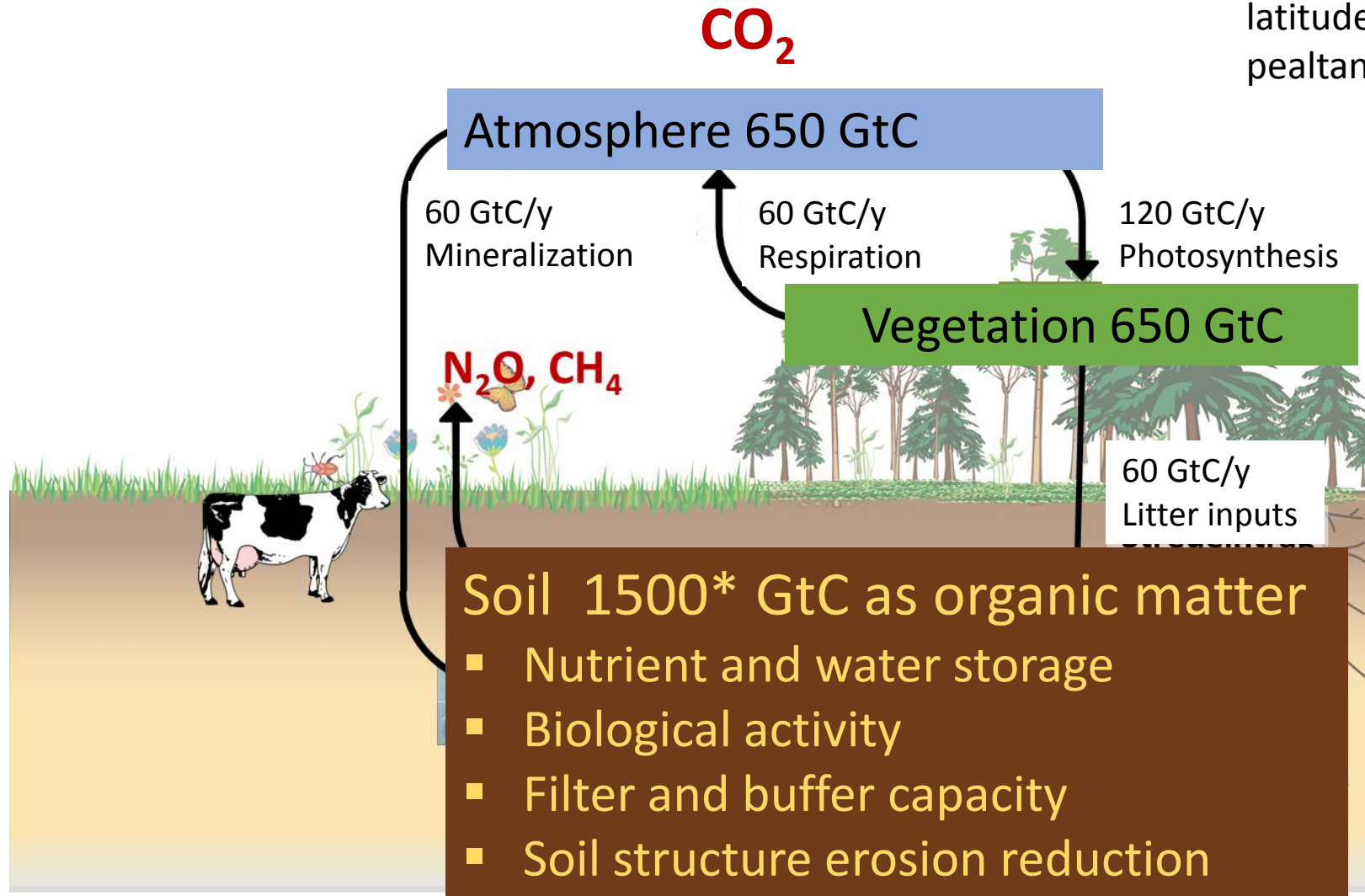


# Soil role in the global C cycle

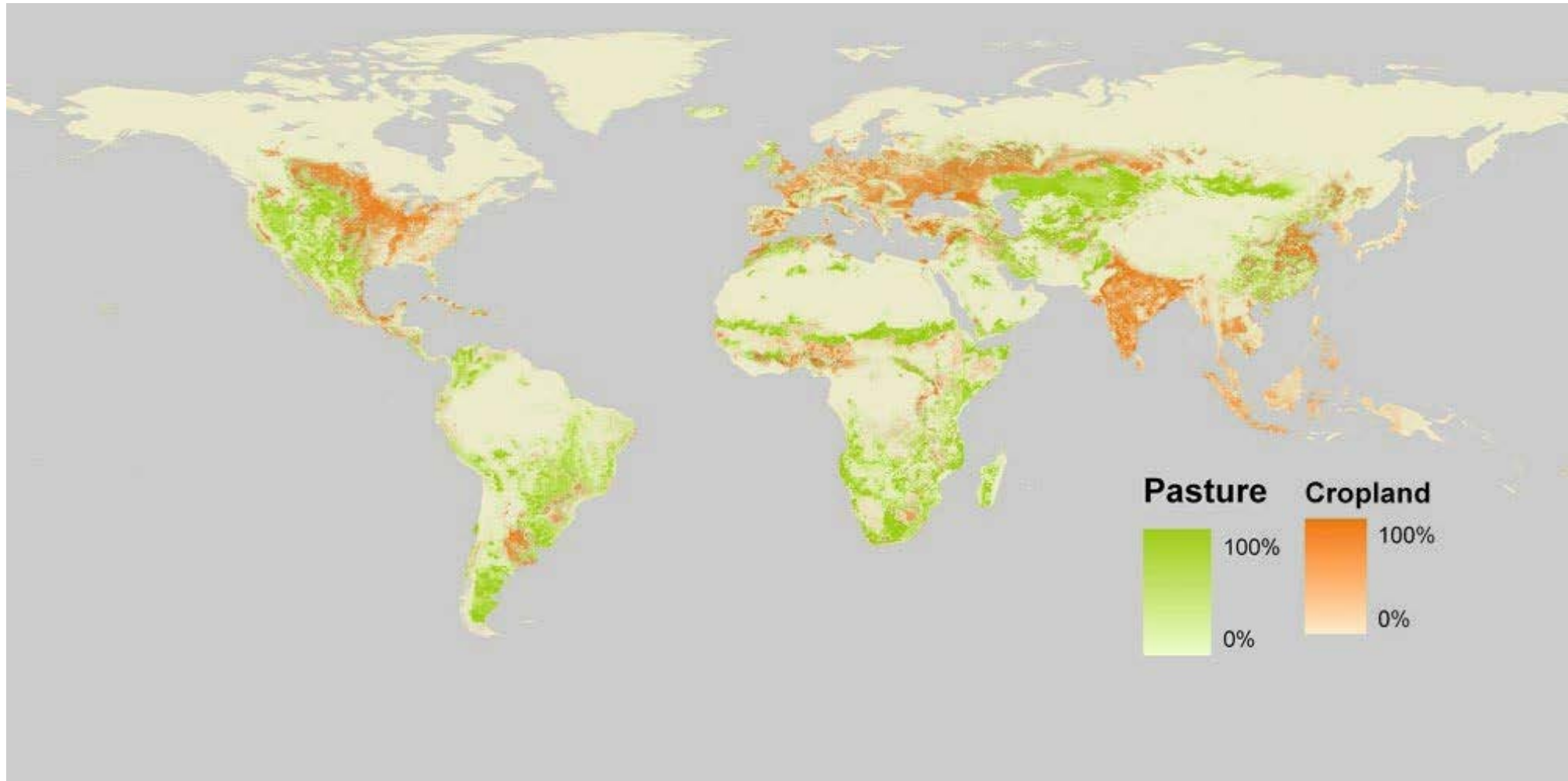
Greenhouse gas emissions

Soil Fertility

Excludes high latitude and peatland soils



>50% of ice-free land area directly modified by humans



maps from the SAGE 7, Center for Sustainability and the Global Environment at the University of Wisconsin-Madison - <http://news.wisc.edu/new-maps-reveal-the-human-footprint-on-earth/#continue>



# Human land management contributes to climate change by altering soils

Livestock →  
increased  
methane  
emissions



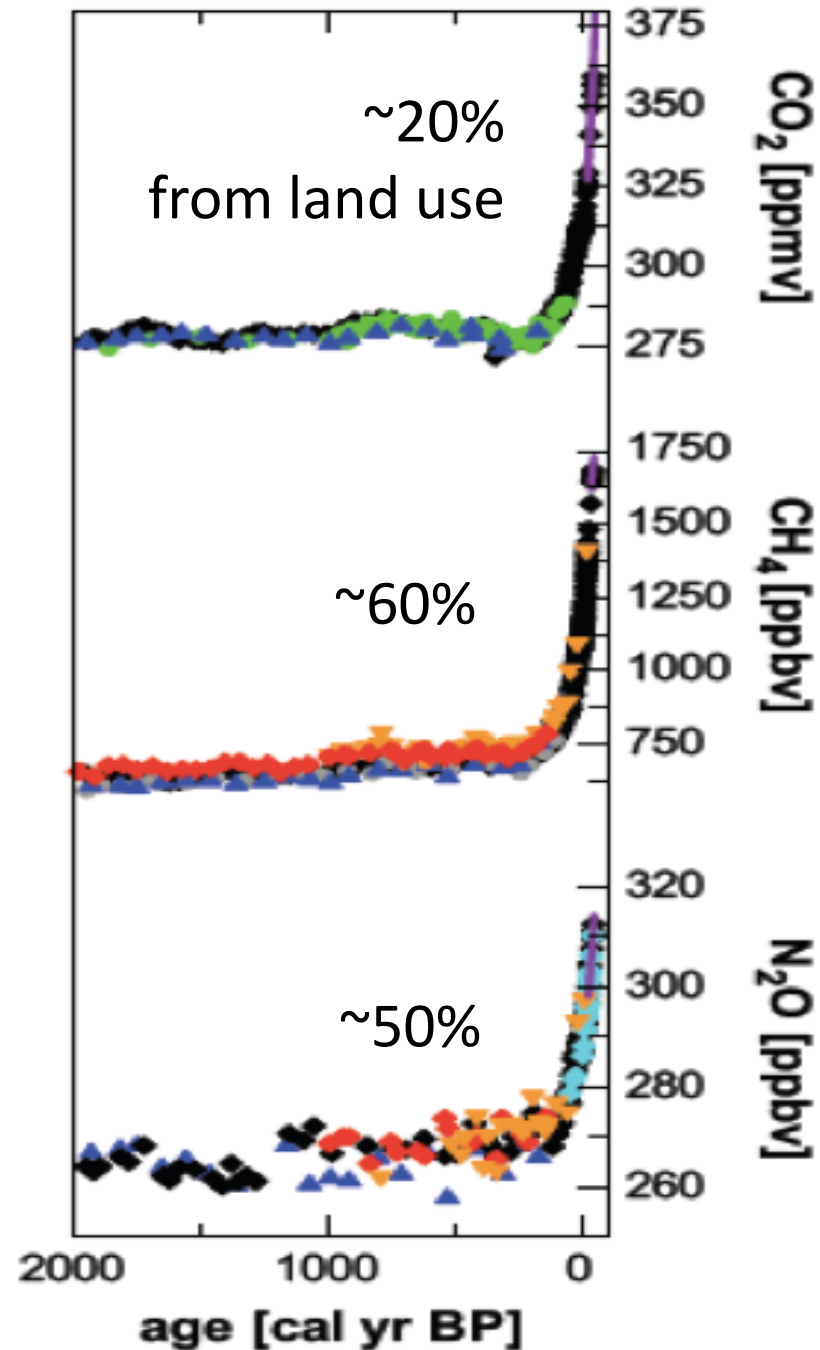
Reduced inputs  
→ loss of SOM  
Fertilizer use  
→ enhanced N<sub>2</sub>O  
emissions



Increases in all three greenhouse gases linked to combined rise of human industry and land conversion in the last century

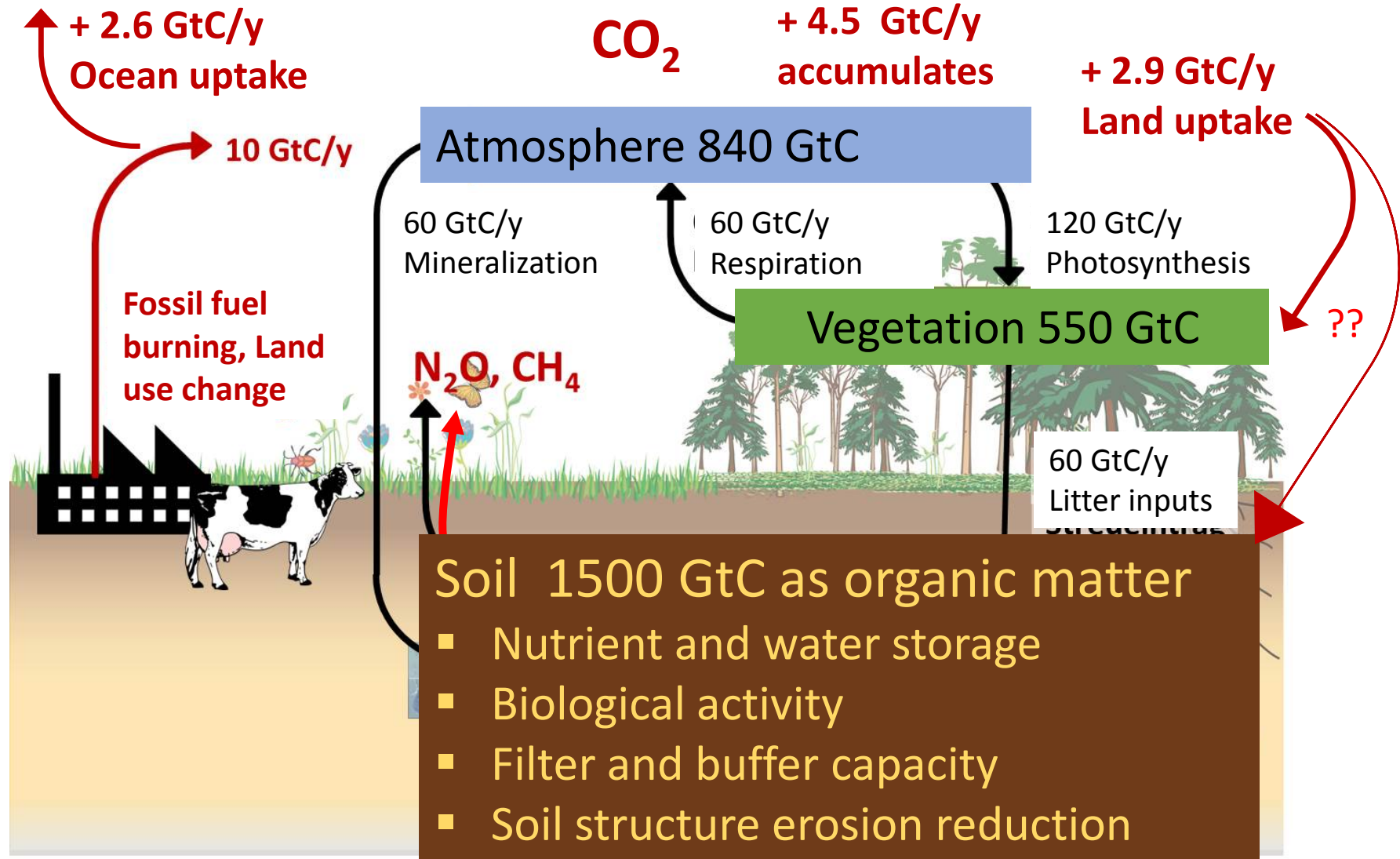
~25% of current radiative forcing from greenhouse gas increases is traceable to land use emissions

Wanner et al. 2008 Quat.Sci. Rev.  
Paustian et al. 2016 Science  
P. Smith et al. 2015 Global Change Biol.



# The Land Carbon Sink

Soil Fertility      Greenhouse gas emissions



**Soil 1500 GtC as organic matter**

- Nutrient and water storage
- Biological activity
- Filter and buffer capacity
- Soil structure erosion reduction

# Can we manage soils to take up even more C ?



**JOIN THE 4‰  
INITIATIVE**

**Soils for  
food security  
and climate**

Building on solid, scientific documentation and concrete actions on the ground, the "4‰ initiative: soils for food security and climate" aims to show that food security and combating climate change are complementary and to ensure that agriculture provides solutions to climate change. This initiative consists of a voluntary action plan under the Lima Paris Agenda for Action (LPAA), backed up by a strong and ambitious research program.

**If we increase by 4‰ (0.4%) a year the quantity of carbon contained in soils, we can halt the annual increase in CO<sub>2</sub> in the atmosphere,** which is a major contributor to the greenhouse effect and climate change

increased absorption of CO<sub>2</sub> by plants :



farmlands,  
meadows,  
forests...



**+4‰ carbon storage in the world's soils**

*= more fertile soils  
= soils better able to cope with the effects of climate change*

International Initiative begun in 2015 as one action to implement the Paris accords

<http://4p1000.org>

# Mitigation of climate change while meeting global demand for food

- Build up organic matter (put back what was lost)
- Apply fertilizer more efficiently
- Amendments (biochar)



- Alter rice cultivars and crop methods to minimize methane emissions



# BUT - What happens to soils in a warmer world?



## Rapid warming of the Arctic Large stores\* of frozen organic C

~1300-1600 PgC Hugelius et al 2014

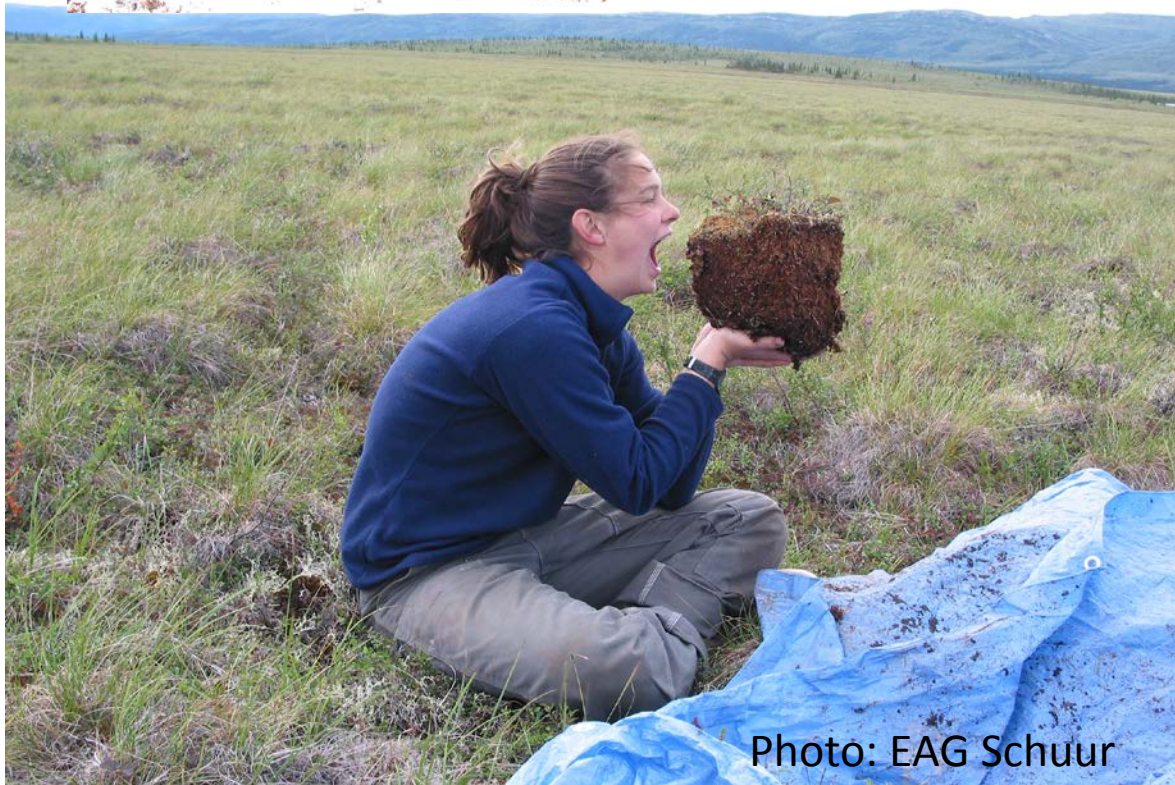
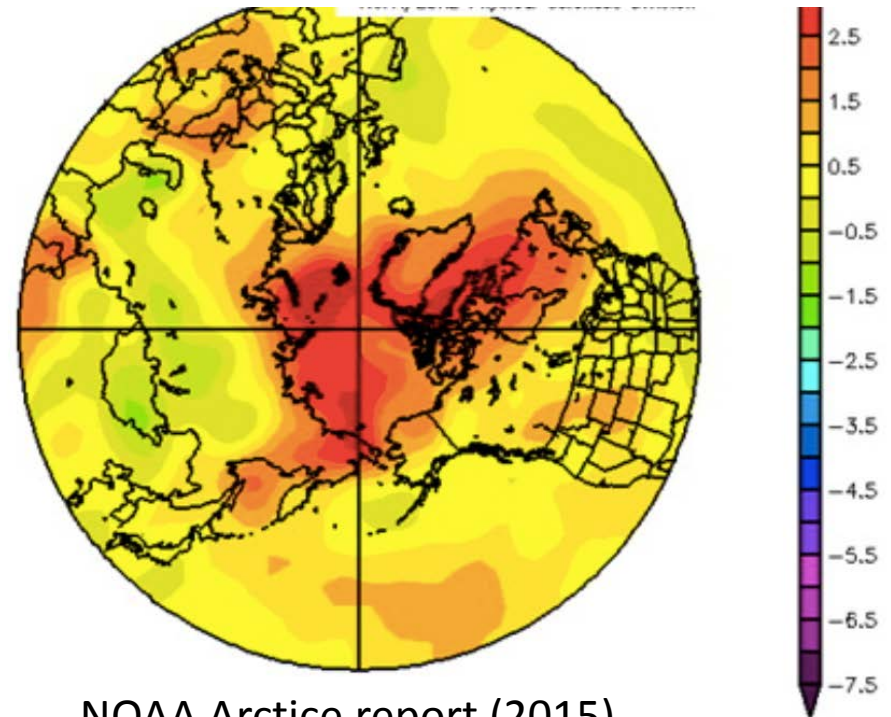


Photo: EAG Schuur

Temperatures in 2009-2014 minus 1984-2000



NOAA Arctic report (2015)

# STATE OF THE SCIENCE

5-15 % of permafrost zone soil carbon vulnerable to release as greenhouse gas this century.

(Schuur et al. 2015 Nature)

- Equivalent to 130 to 160 billion tons carbon
- Magnitude similar to current emissions from deforestation



# Summary:

- What we do to soils has consequences for the atmosphere and climate
  - Use best science to balance food demand with other soil services
- Uncertainties remain large at global scales
  - How much do soils contribute to the land C sink?
  - How will soil C stores respond to temperature rise?
- Role of science is both to increase fundamental understanding of how soils operate and to assess management options and tradeoffs