Carbon sequestration in soils



Danube Countries Workshop
29.03.2011, St. Pölten

Walter W. Wenzel & Alex Dellantonio

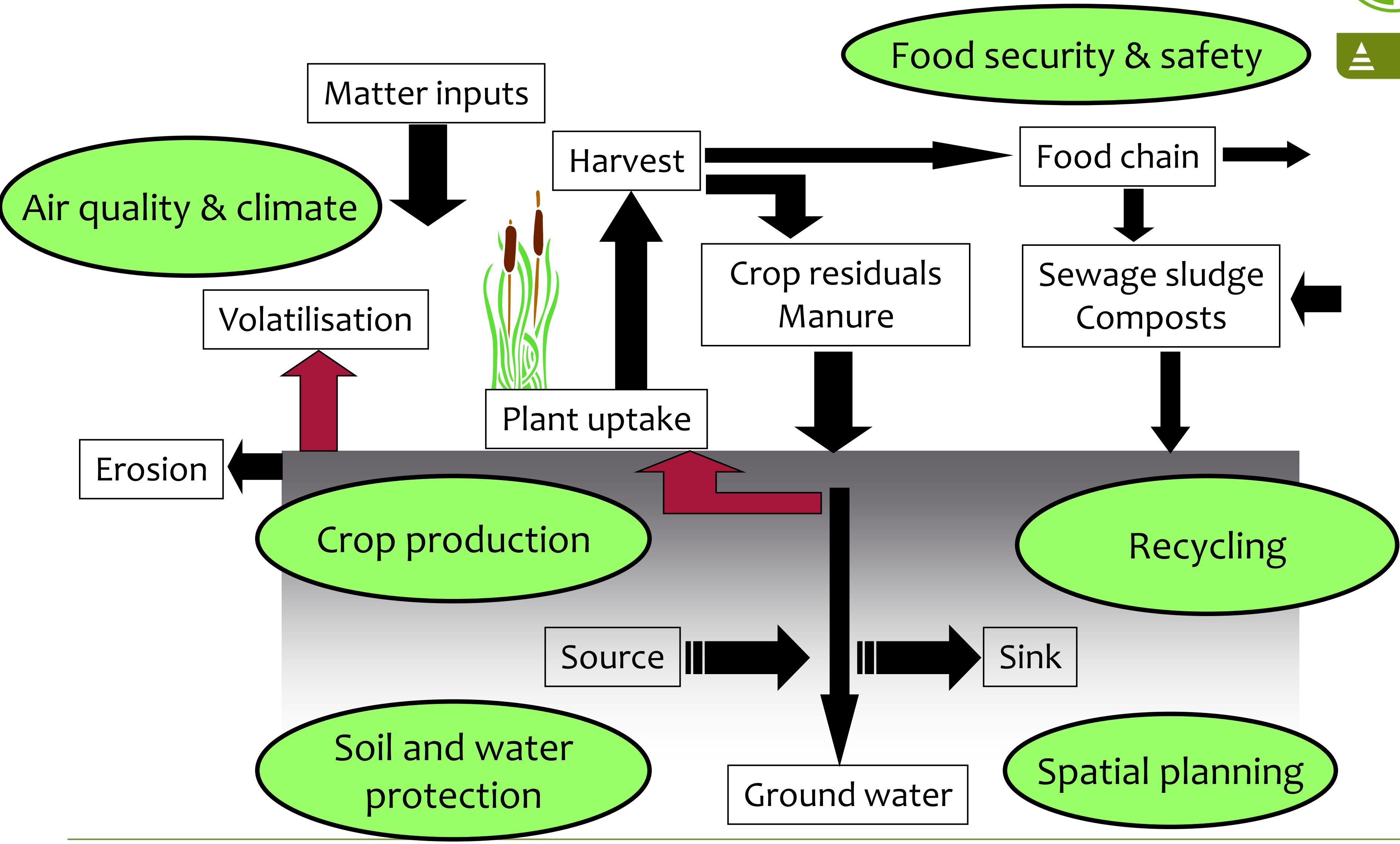
University of Natural Resources and Life Sciences, Vienna
Institute of Soil Research

Topics of the talk

- Global carbon cycle – carbon pools
- Carbon sequestration in soils
- Carbon sequestration and soil/land management
- Future prospects

Fig. 3. Subsidence of soil in Florida due to oxidation of organic matter following drainage. When the post was installed in 1923, with its base on bedrock, its top was level with the soil surface. (Photo courtesy of D. Morris, USDA-ARS, Canal Pt. FL.)

Picture from: ELSEVIER Agriculture Ecosystems & Environment www.elsevier.com/locate/agee


Food security & safety
Matter inputs
Harvest
Food chain
Air quality & climate
Crop residuals
Manure
Sewage sludge
Composts
Volatilisation
Plant uptake
Erosion
Crop production
Recycling
Source
Sink
Soil and water protection
Ground water
Spatial planning

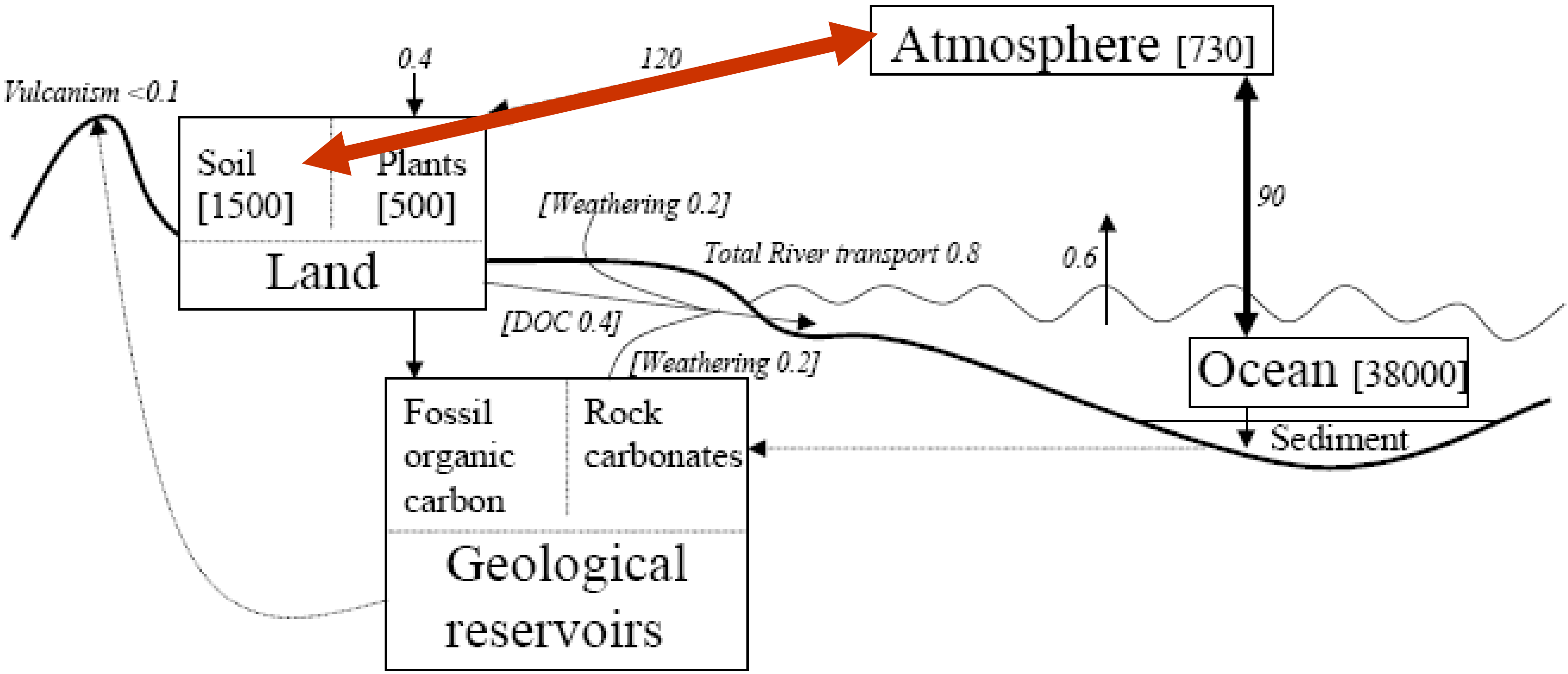
Questions

- Climate change – the role of soils?
- Source or sink?
- What can be achieved by improved soil management?
- What do we know, where are uncertainties?

Global carbon cycle

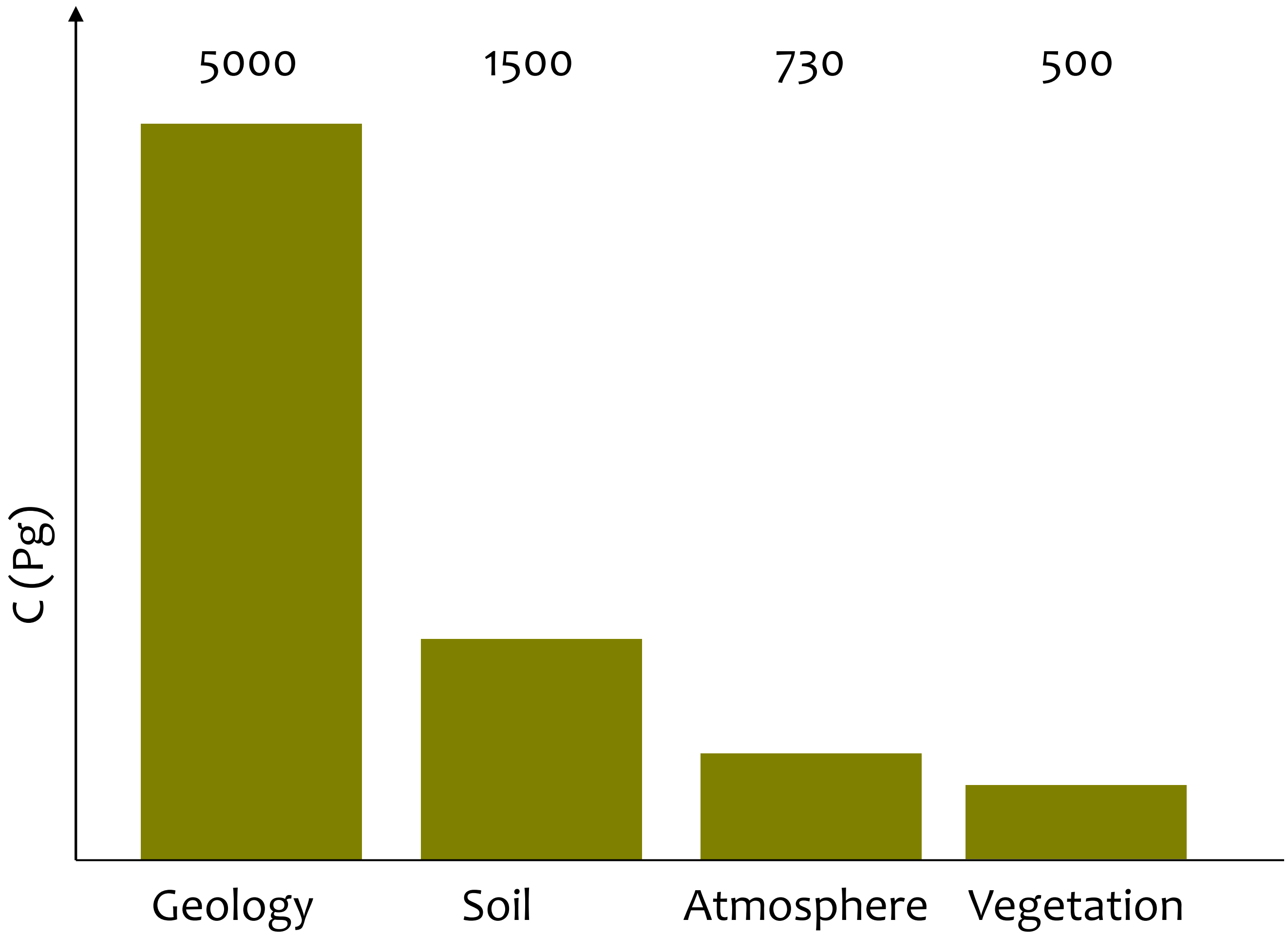
Schematic overview global carbon cycle (Pools and Fluxes in Pg) (1 Petagramm = 10^{15} g =10^9 t)

Schils et al. (2008)



Global C Pools

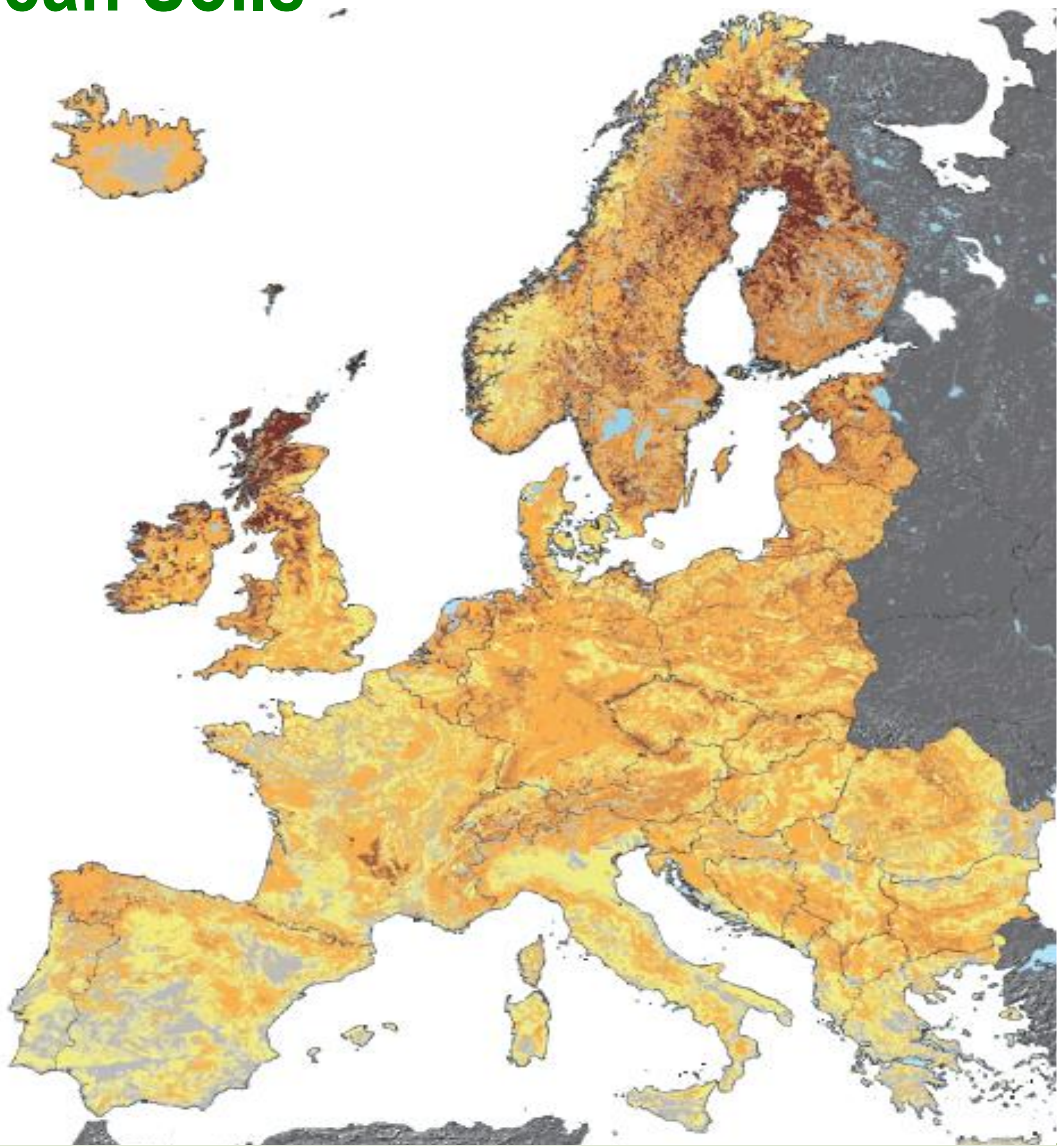
Global C Pools in Pg (1 Petagramm = 10^{15} g = 10^9 t)

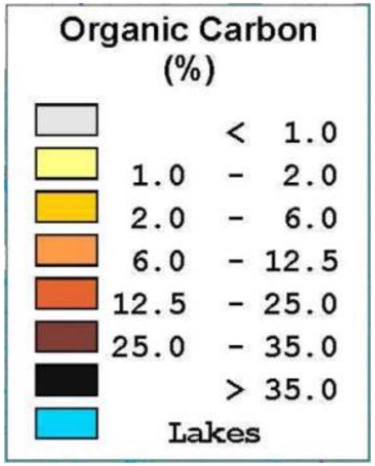


Schils et al. (2008)

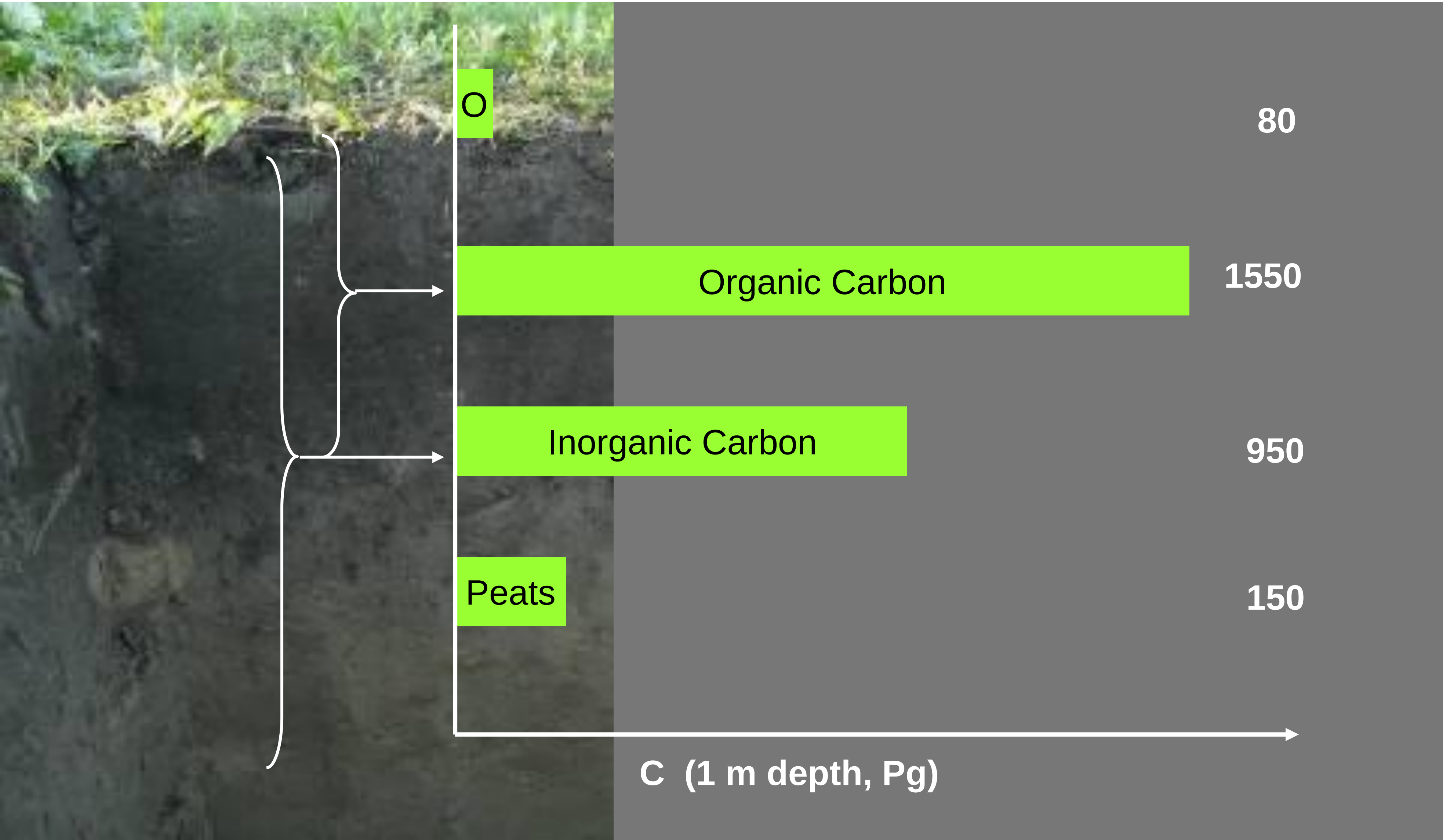
C Pools in European Soils

Soil C pools
Austria: 1.2-1.4 Pg (1.5%)
Europe: 75.3-79.7 Pg
(Schils et al., 2008)





Global C-Pools in soils



C-Pools & Storage in soils

biogeochemical processes

Process: Photosynthetic transformation of CO2 into biomass

$$6\,CO_2 + 12\,H_2O \xrightarrow{h\nu} C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

Time scale: **10 - 100 years**

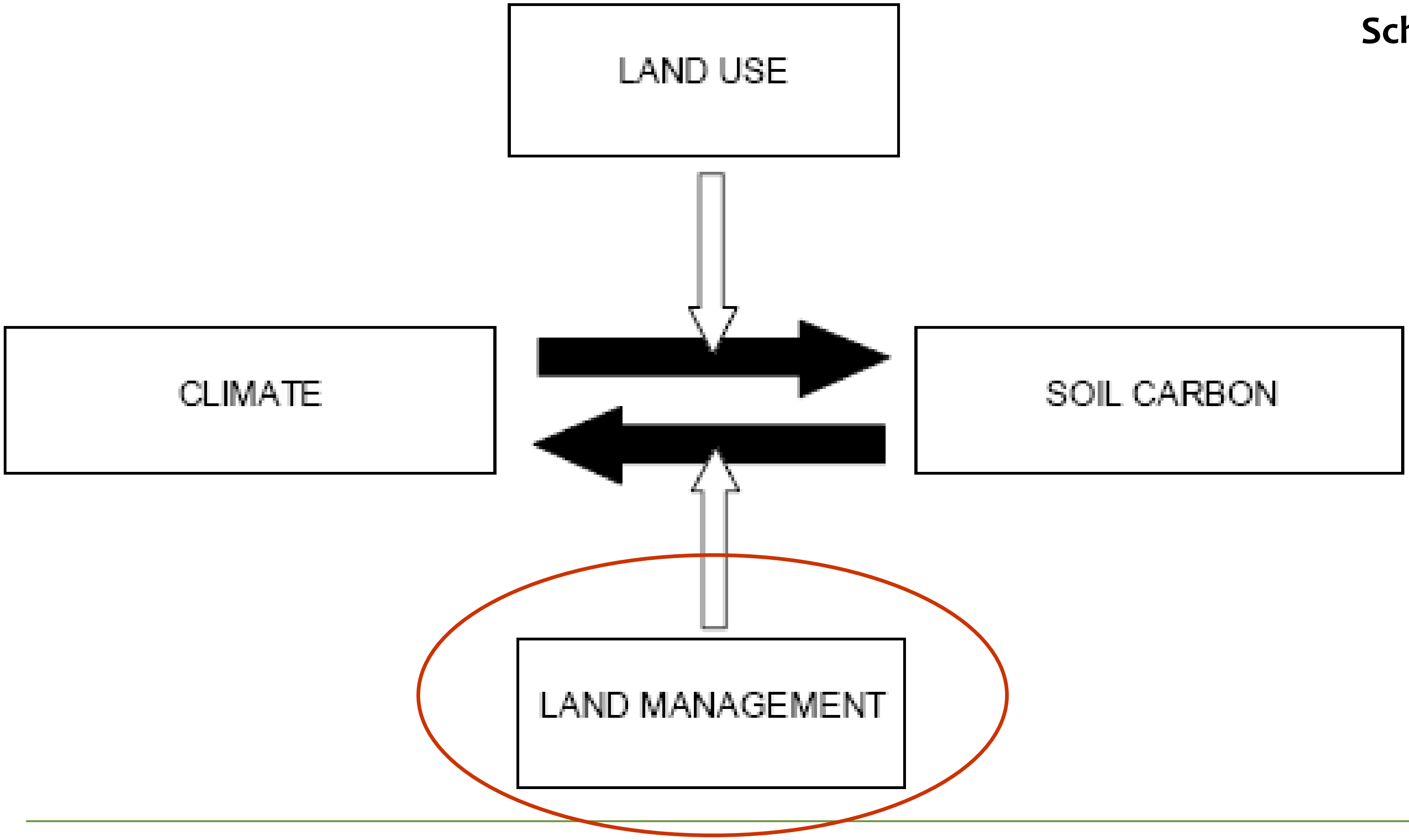
process: silicate weathering

$$Mg_2SiO_4 + 4CO2 + 4H_2O \longrightarrow 2\,MgCO_3 + SiO_2 + 2CO_2 + 2\,H_2O$$

time scale: **>10000 years**

C-storage & soil management

Schils et al. (2008)



C-storage & soil management

- aim
  - CO_2-storage by increase of organic matter in soil
  - reduction of losses
- land management
  - tillage
  - fertilizing
  - cover crops
  - crop rotation
  - organic matter input

C-storage & soil management

Potentially successful measures for C-storage

C-storage potentials in the EU-15 in the first commitment-period Kyoto (Mt C y^{-1})

Freibauer et al. (2004)

Cropland management

- 5.5 — Promote organic inputs (crop residues, cover crops, FYM, compost, sewage sludge)
- 3.8 — Organic farming
- <2.5 — Conservation / zero tillage

Grassland management

- 4.1 — Maintain permanent shallow water table and rewet peat soils

Permanent vegetation cover on set-aside land

- 4.1 — Perennial grasses
- 4.1 — Woody bio-energy crops (afforestation, short rotation coppice plantations)

Total: 16-19 Mt C y^{-1}

C-storage & soil management

IPCC-factors, 20 years

Reduzierte Bodenbe-arbeitung *reduced tillage*	Herabgesetzte Bodenstö-rung/seichte Bodenbearbeitung ohne volle Wendung des Bo-dens *reduced soil disturbance (shal-low – without full soil inversion)*	1,03
Minimalbodenbe-arbeitung *no-till*	Nur minimale Bodenstörung in der Saatzone *only minimal soil disturbance in the seeding zone*	1,10

Most studies seem to confirm the positive effect of reduced tillage, but…

C-storage & soil management

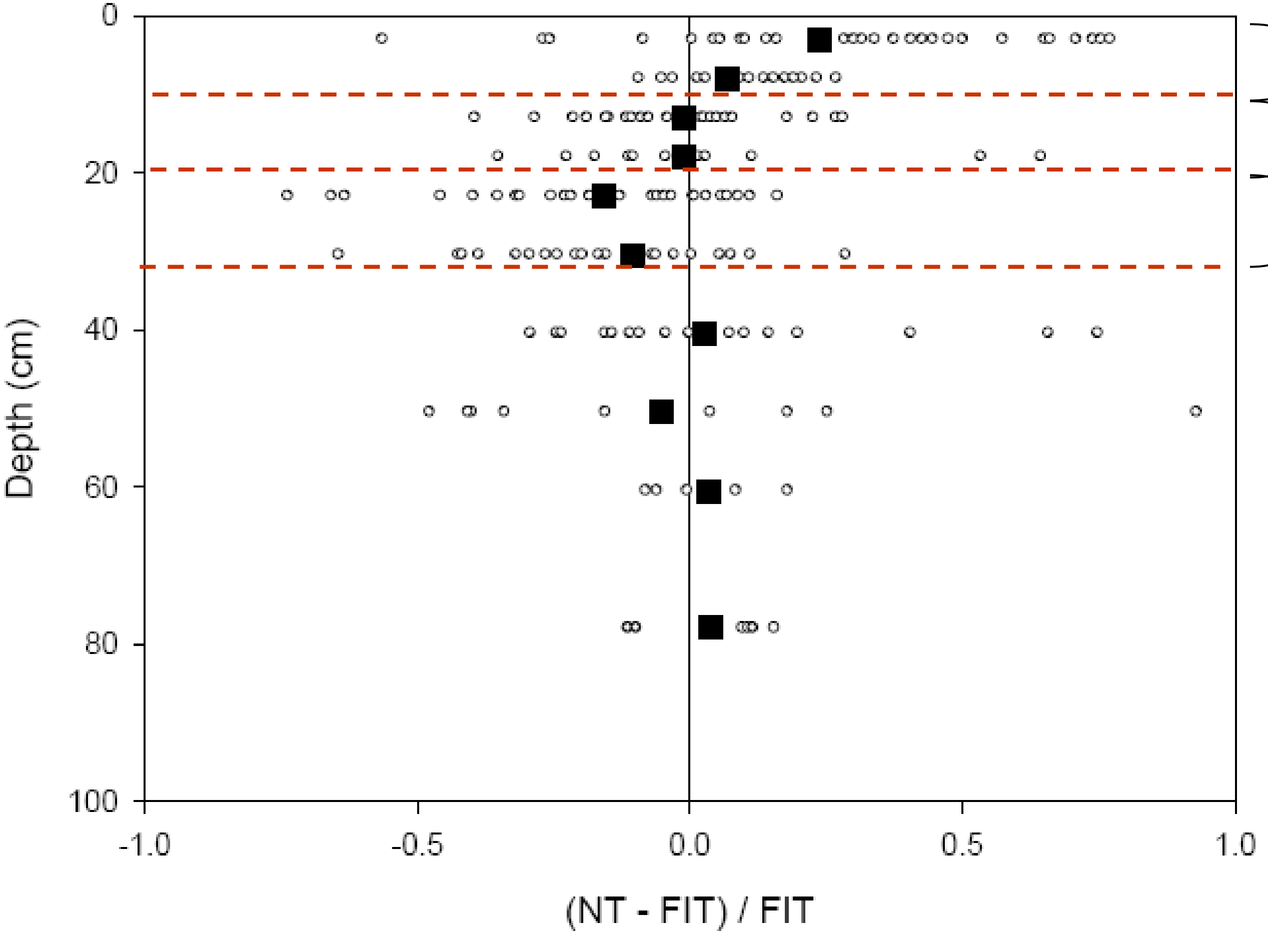
…. different C-distribution in soil profile

…. meta analysis shows no significant differences (controversial debate among mathematicians!)

…. large variations between studies

…. many studies < 20 cm depth

Sanderman and Baldock, 2010



$C_{no\text{-}till} > C_{till}$

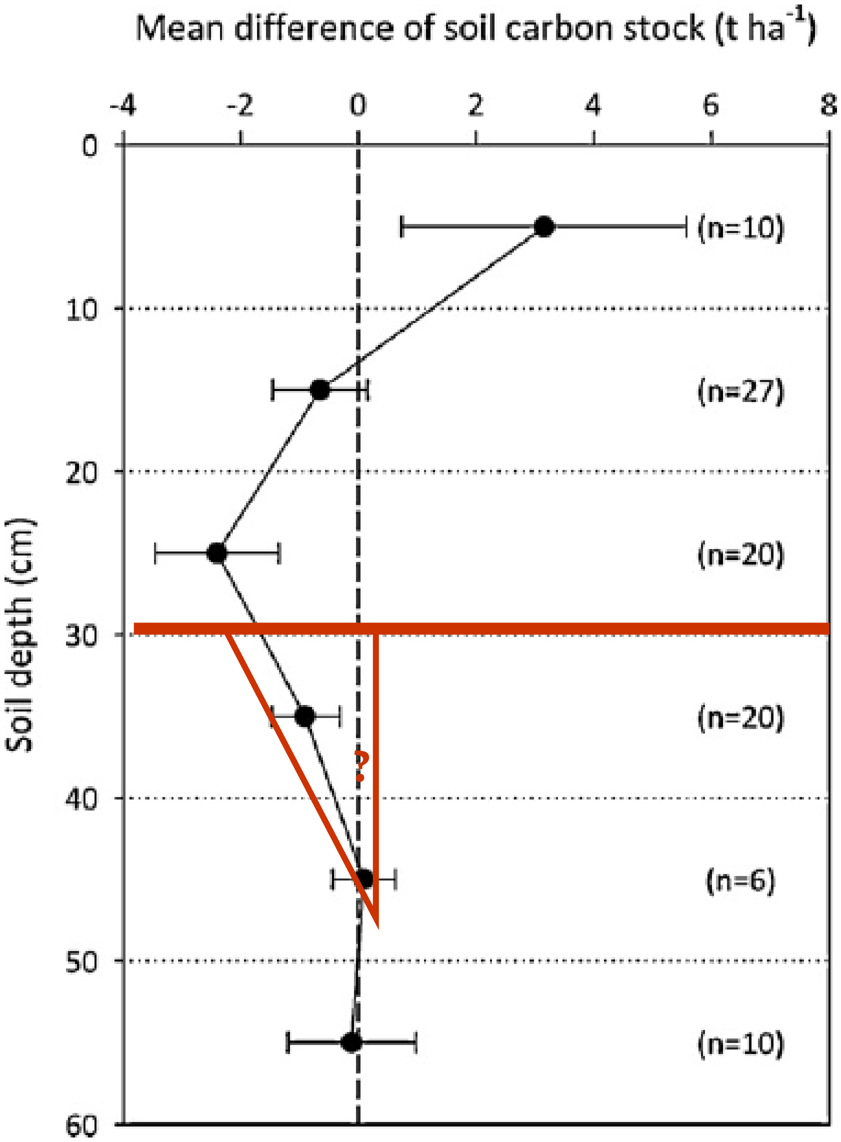
$C_{no\text{-}till} = C_{till}$

$C_{no\text{-}till} < C_{till}$

> 20 cm more C in tilled plots

C-storage & soil management

…. one more study shows no significant difference



Luo et al., 2010

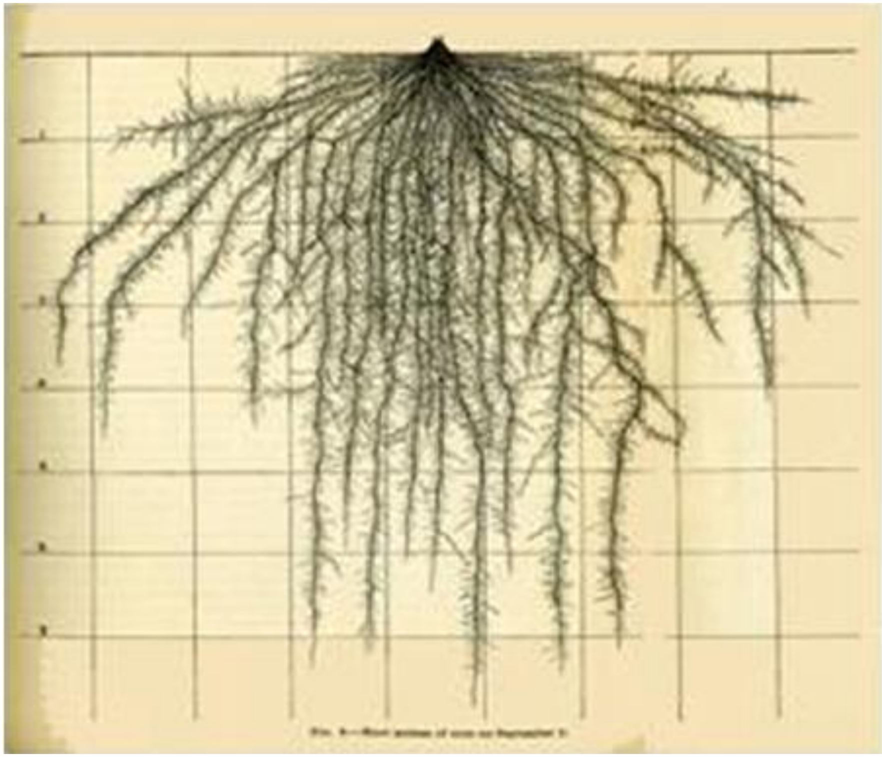
Analysis of 69 paired experiments:
- significant C-increase 0-10cm
- significant C-decrease 20-40cm

50% of studies considered by IPCC end here

C-storage & soil management

…. overestimating of storage potential by IPCC?

…. on the other side negelecting additional potentials?



Baker et al., 2007

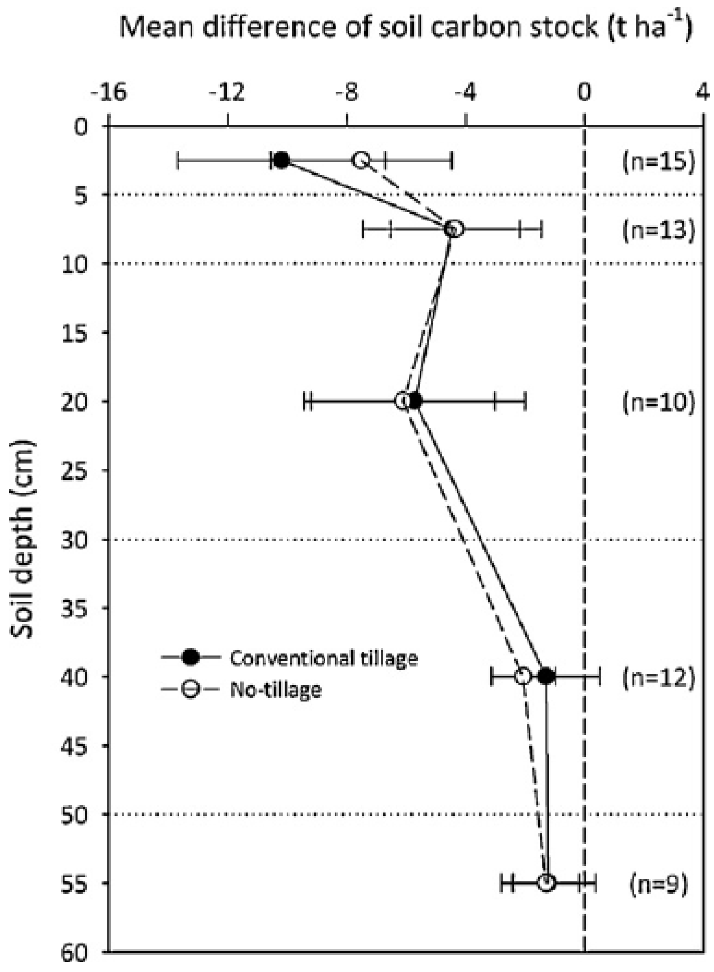
} 30 cm

-> rhizodeposition (up to 50% of C)

Using stable isotope fractionation, Wilts et al. (2004) estimated that the ratio of SOC derived from below-ground plant C to that derived from above-ground stover was nearly 2:1 in long-term corn plots, further emphasizing the importance of root systems in C sequestration.

C-storage & soil management

„Dilemma of previous land use“



◄ **difference to natural undisturbed soil „status quo ante“**

both till and no-till have less C

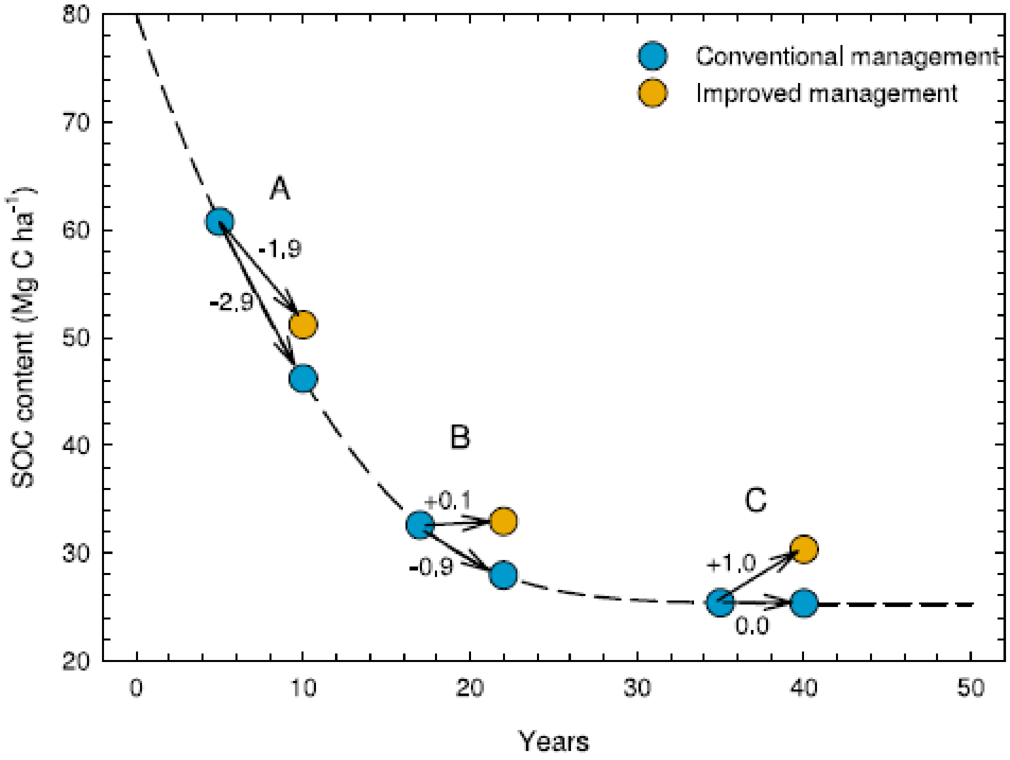
-> base line?

Luo et al., 2010

C-storage & soil management

„dilemma of previous land use "

…. „dynamic view"



assumption
deltaC = 5 Mg C /ha in 5 years

only in case „C" significant net sequestration

Sanderman & Baldock, 2010

Difference: net sequestration vs. avoidance of emissions!

C-storage & soil management

Methodological problems estimating C-pools

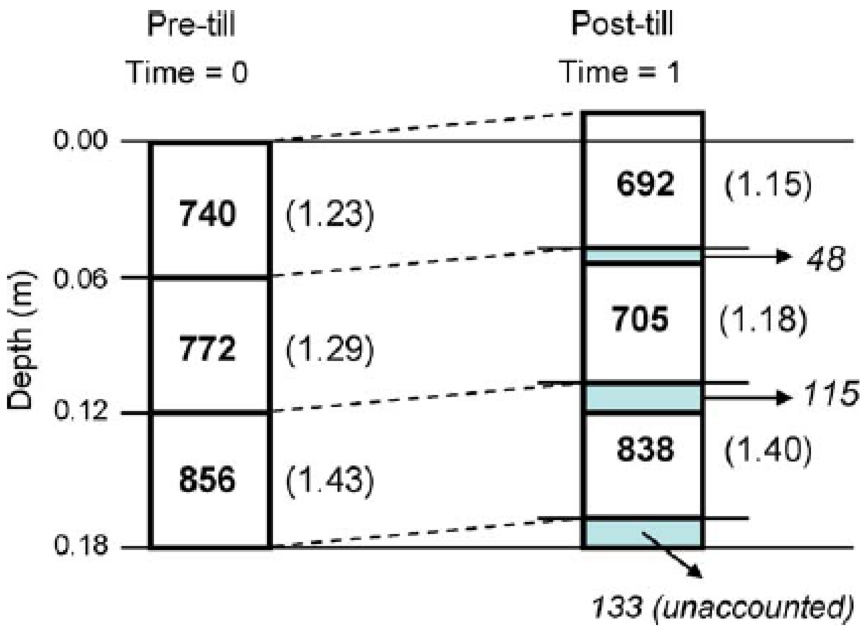


Fig. 1. Hypothetical example of the original equivalent soil mass calculation in a tilled soil. Numbers in bold indicate soil mass (Mg ha^{-1}) sampled at time = 0 and time = 1 and those in parentheses indicate bulk density (Mg m^{-3}). Numbers in italics indicate the portion of soil mass from a deeper layer that is used to attain the equivalent soil mass for a layer.

without considering changes in bulk density
->
„plowing effect“ ~ 5,6%

several studies neglect this fact

Determining soil carbon stock changes: Simple bulk density corrections fail

Juhwan Lee[a,*], Jan W. Hopmans[b], Dennis E. Rolston[b], Sara G. Baer[c], Johan Six[a]

C-storage & soil management

Methodological problems estimating C-pools

All GHG have to be considered (CH_4, N_2O)

Rochette et al. 2008
„No-till can result in incremental N_2O emissions that can **more than offset** the soil CO_2 sink during the first year of adoption in a heavy clay soil"

Li et al. 2005
„Reduced tillage, enhanced crop residue incorporation, and farmyard manure application:
- increased soil C-sequestration,
- increased N_2O emissions,
- had little effect on CH4.

Over 20 years, increases in N_2O emissions **offset 75–310% of the carbon sequestered**, depending on the scenario.

C-storage & soil management

My talk should:

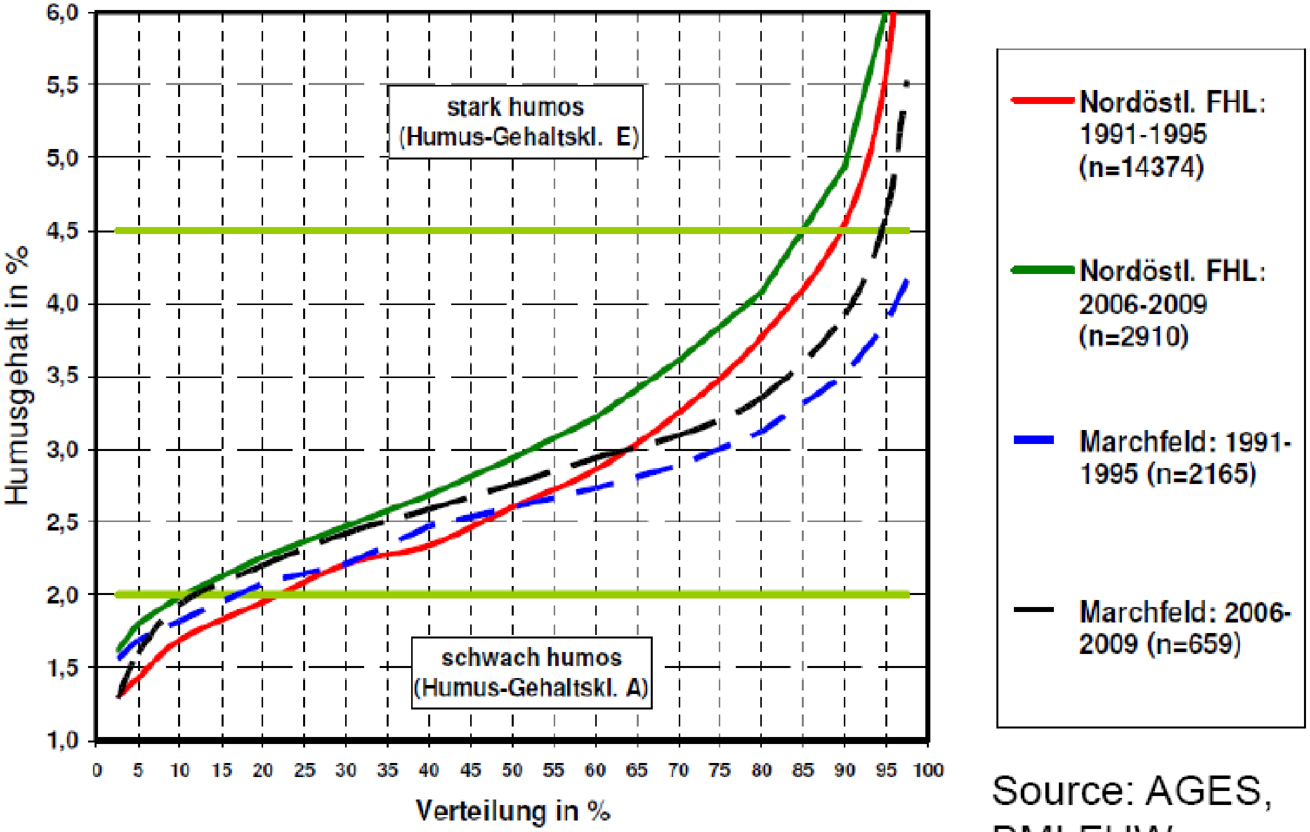
A) not be understood as a „defence of the plow“

several advantages of reduced tillage:
- erosion
- fuel consumption
- most likely increase of soil C

B) not be understood as a „belittling of the importance of humus“:
- fertility
- flood protection
- nutrient cycling

Conclusions

applying a set of measures has proven successful

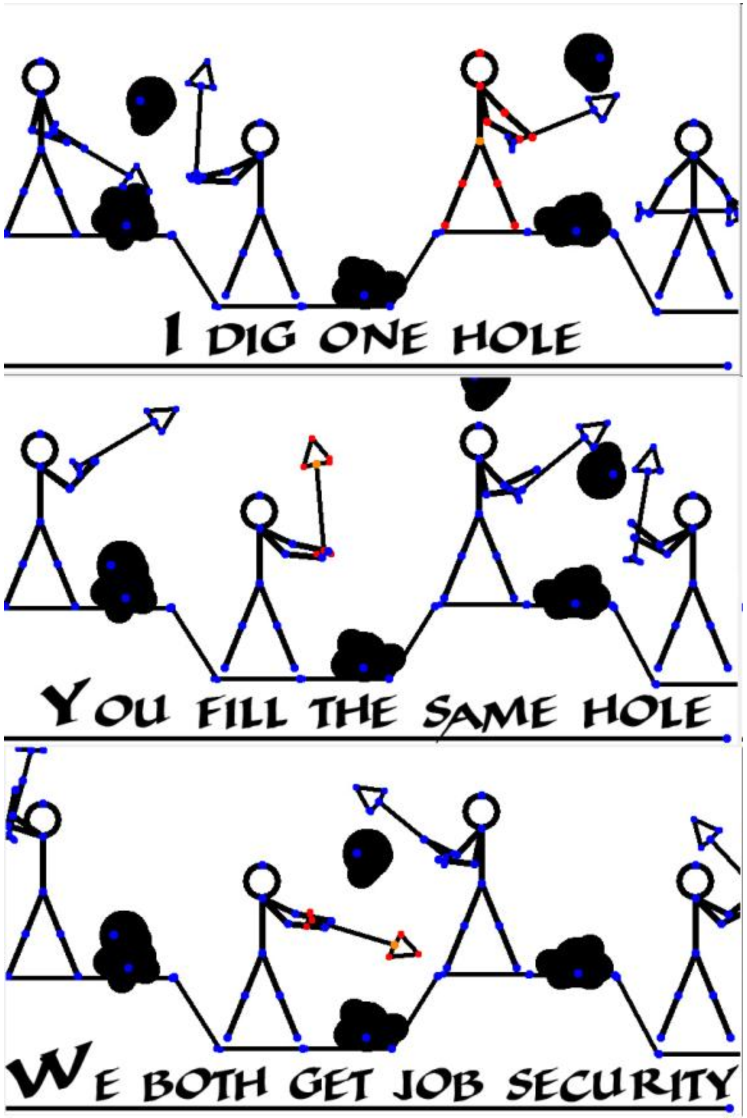


Source: AGES, BMLFUW

ÖPUL-Evaluierung – Auswirkungen von ÖPUL-Maßnahmen auf die Nährstoffverfügbarkeit österreichischer Böden

Conclusions

- long term sustainable policies (>20 years)
- permanent measures (losses of CO_2 and N_2O)
- always check for unwanted effects (N_2O or CH_4 emissions, net balance!)
- large uncertainties in determining C storage
- consider saturation of C-pools in soils depending on soil type, climate etc
- ground water protection (175 kg N!) -> no indiscriminate application of organic matter when it comes to emissions trading



Thank you for your attention

http://pithypontifications.files.wordpress.com/2010/03/digging.jpg