Carbon farming with straw incorporation - A reality check

PD Dr. Axel Don und team

Thünen Institute of Climate-Smart Agriculture

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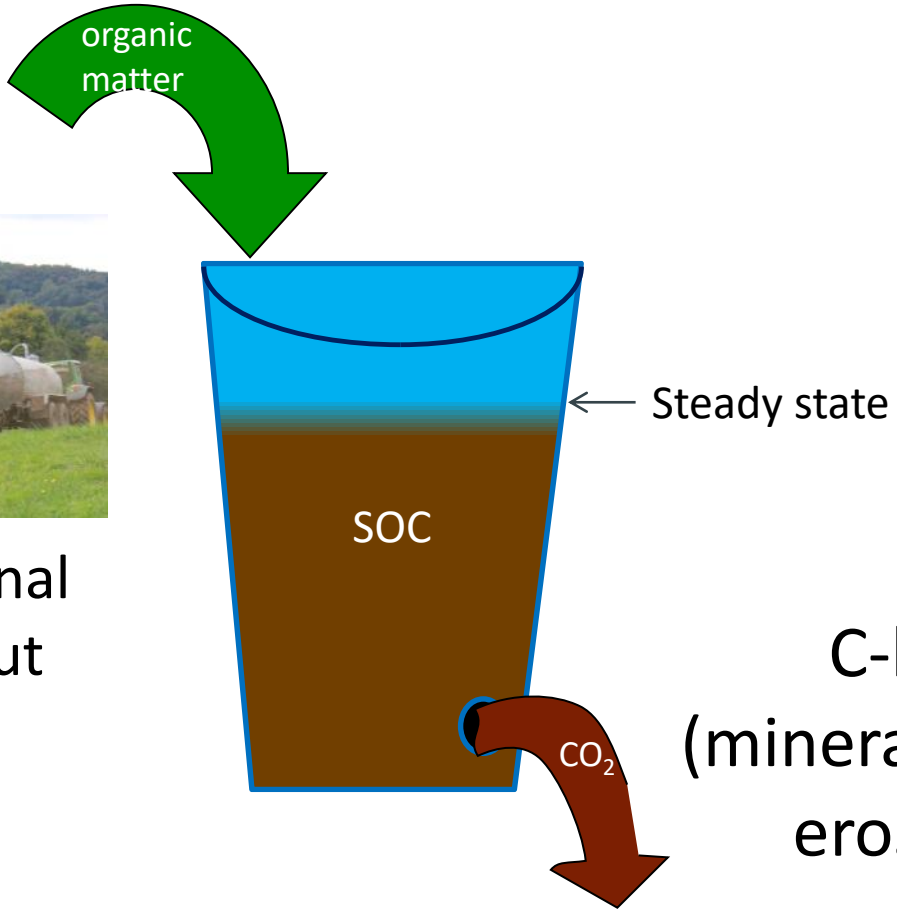
Agri benchmark and GRA webinar

How does C sequestration works ?

Internal
C-input

External
C input



C-loss
(mineralisation,
erosion)

Internal C input

More production

- Crop rotation/ crop variety
- Cover crops/ inter crops (green manure)
- Perennial crops/agroforestry
- Rooting density/depth
- Fertilisation
- Other management options

Less removal

- Straw removal
- Harvest
- Crop residual removal

External C input

Liquid manure

Farm yard manure

Compost

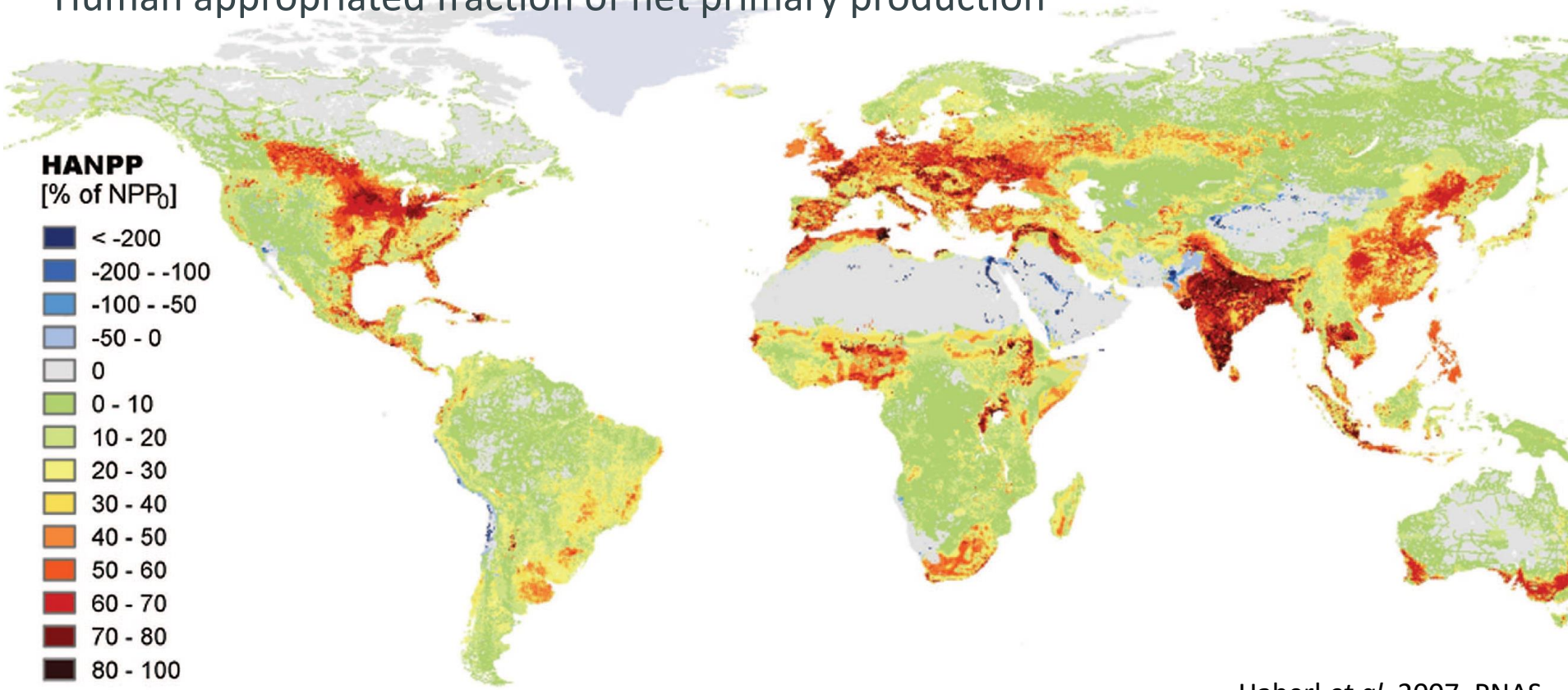
Sewage sludge

(Lime)

C Sequestration with external C input is no climate mitigation measure (e.g. Powlson *et al.* 2011 EJSS)

How much C is extracted from ecosystems with harvest?

Human appropriated fraction of net primary production

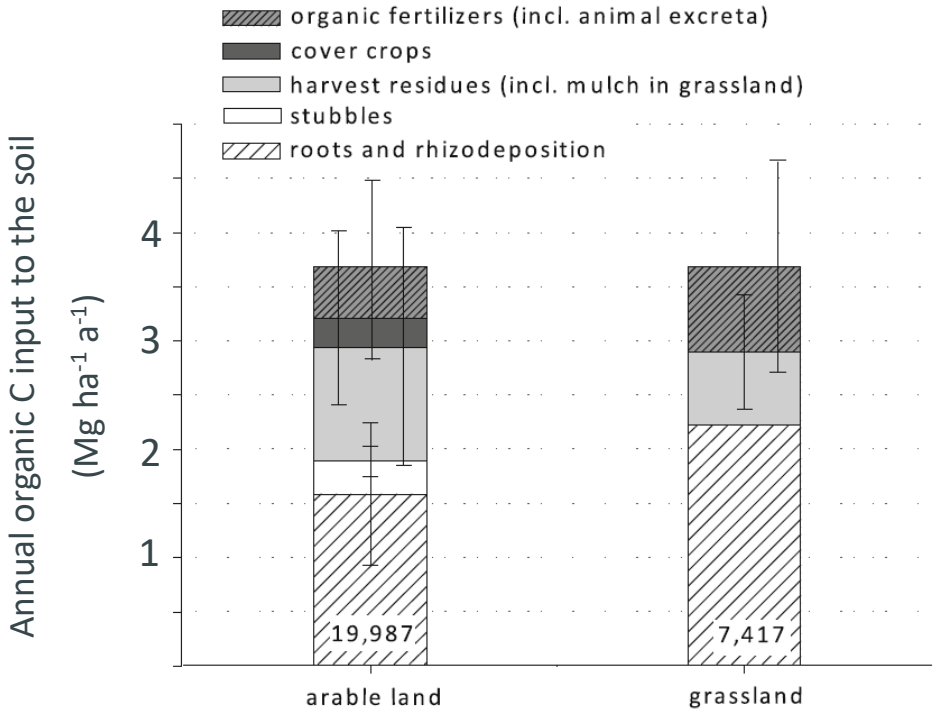


Haberl *et al.* 2007, PNAS

➡ C input to the soil is management driven

Straw biomass and removal

- Only about 50% of the straw can be removed
- A large proportion is left on the field as stubble, chaff, and uncollected straw (Powlson et al.2011, Agro. J.).



Case study Germany:

Per hectare 3 tonnes straw is harvestable

This equals 28% of total C input to the soil

Jacobs *et al.* 2020, Nutr Cycl Agroecosyst

Straw properties

Material	C:N Ratio
rye straw	82:1
wheat straw	80:1
oat straw	70:1
corn stover	57:1
rye cover crop (anthesis)	37:1
pea straw	29:1
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Ideal Microbial Diet	**24:1**
rotted barnyard manure	20:1
legume hay	17:1
beef manure	17:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1

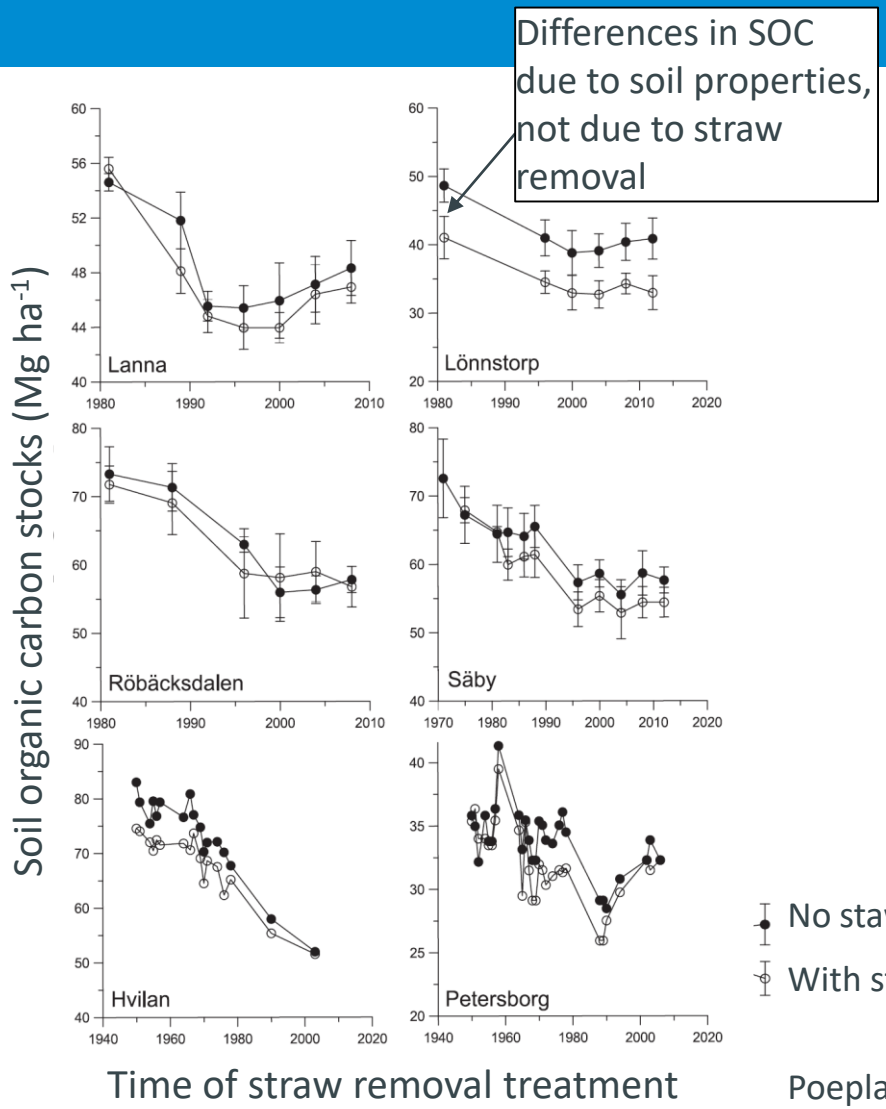
USDA 2011

Straw has a wide C/N ratio,

is N-poor

has a high lignin content

Straw removal and soil organic carbon: Sweden



Swedish Long-term field experiments

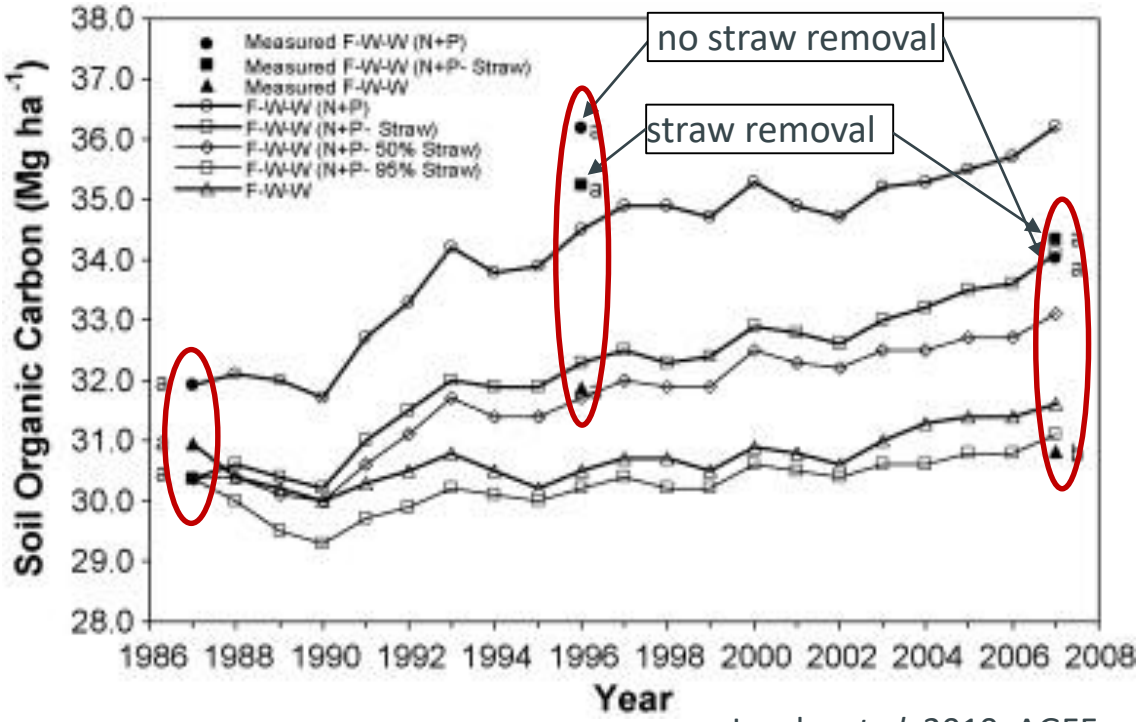
Duration of 27–56 years

Sampling 0-20 cm depth

➡ No significant effect of straw removal

Poeplau *et al.* 2015, Geoderma

Straw removal and soil organic carbon: Canada



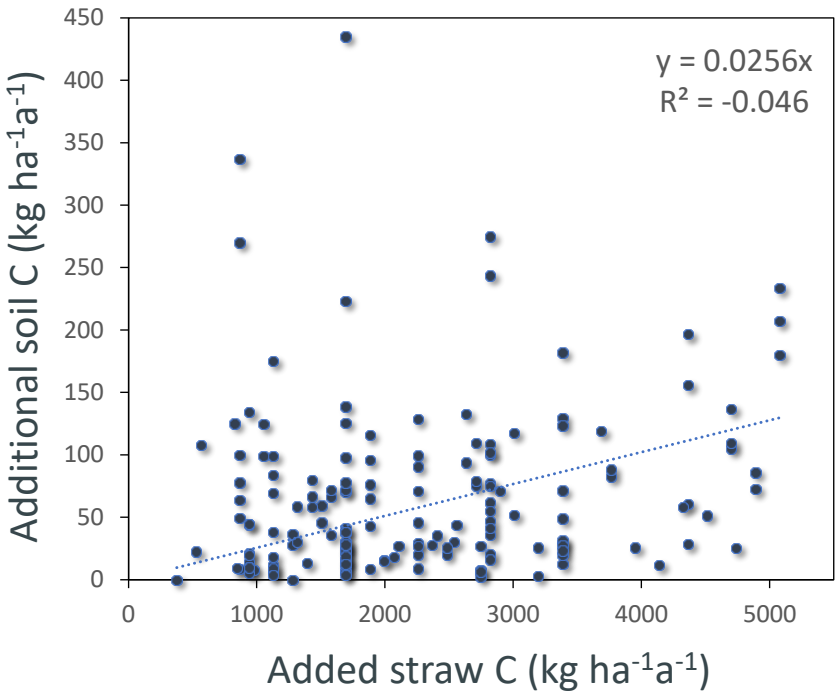
Lemke *et al.* 2010, AGEE

- Long-term field experiment from 1958 to 2007
- clay soil
- sub-humid southeast Saskatchewan, Canada

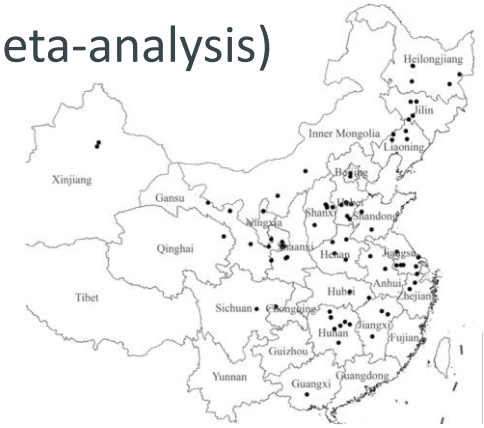
Straw removal reduced C inputs by only 13%

➡ No significant effect of straw removal

Straw removal and soil organic carbon: China



169 paired soil data (meta-analysis)



3 to 30 years old field experiments

Higher straw removal effect: +12% soil-C

Lu *et al.* 2015, Mitig Adapt Strateg Glob Change

- No relation between straw C input and additional soil C
- Only 2.6% of straw-C is retained as soil C

Straw removal and soil organic carbon: Global

Out of 22 field experiments, only four showed significant effects of straw removal on soil carbon stocks

Lemke *et al.* 2010, AGEE

A global meta analysis quantified straw removal effect with SOC loss of 0.1 t ha^{-1} a^{-1}

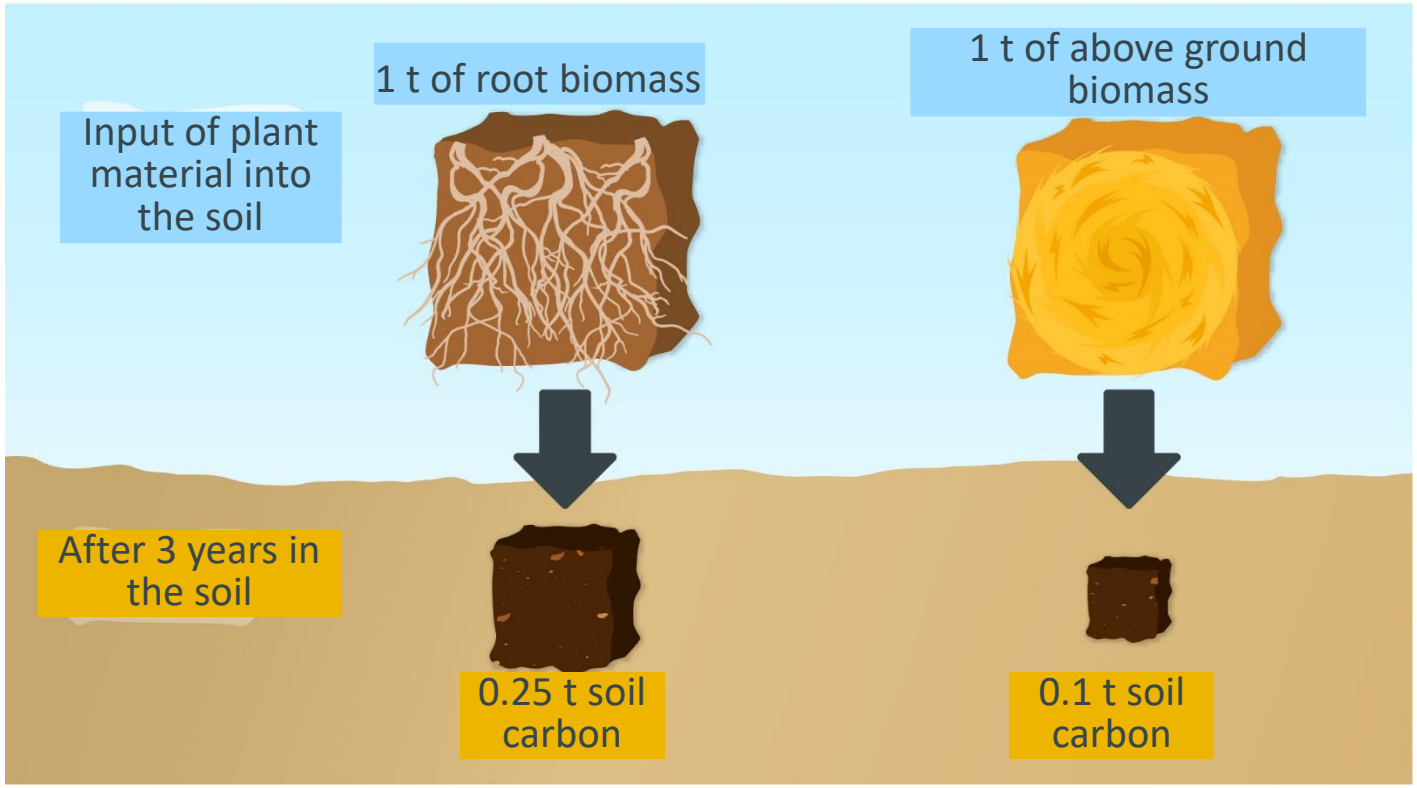
Bolinder *et al.* 2020, Mitigat. Adapt Strategies Global Change

SOC changes for the effects of:

	Weighed by *N*	*N*
AG crop residue removal	117	279
Cover crops	331	176
ROM—manure	409	217
N-fertilization	233	183

in kg C $ha^{-1}a^{-1}$

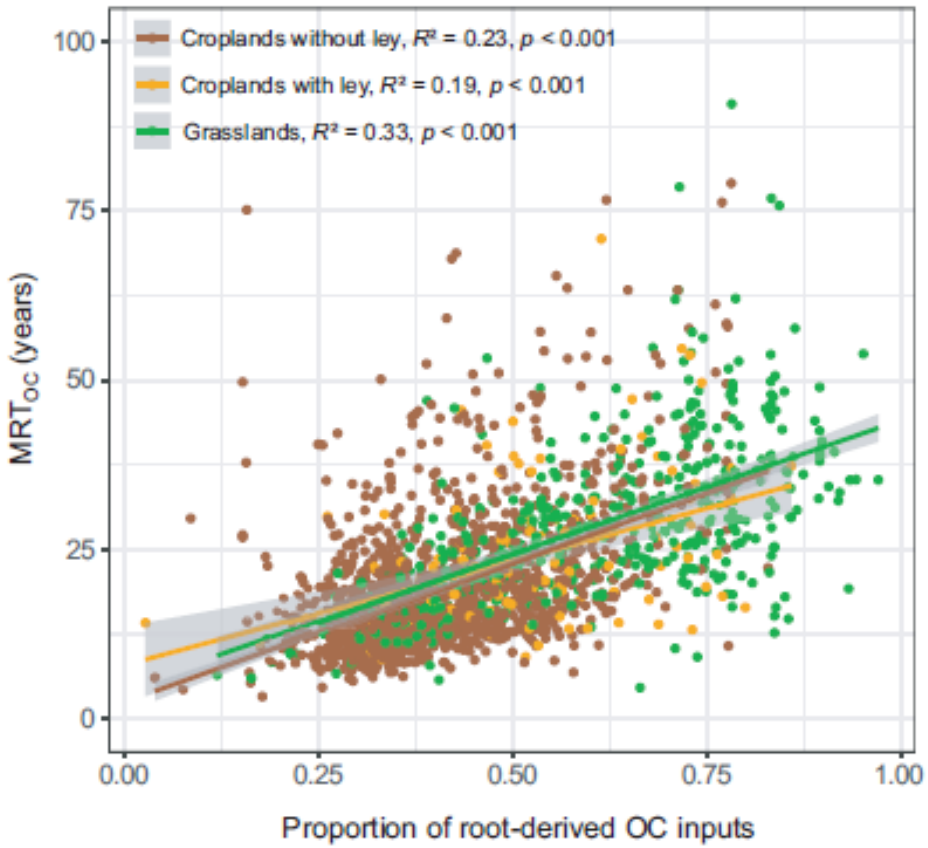
Roots are much more important than straw



2 to 3 times more soil carbon is build with roots compared to straw

(Kätterer *et al.* 2011 AGEE; Rasse *et al.* 2005 Plant Soil; Xu *et al.* 2019 EJSS)

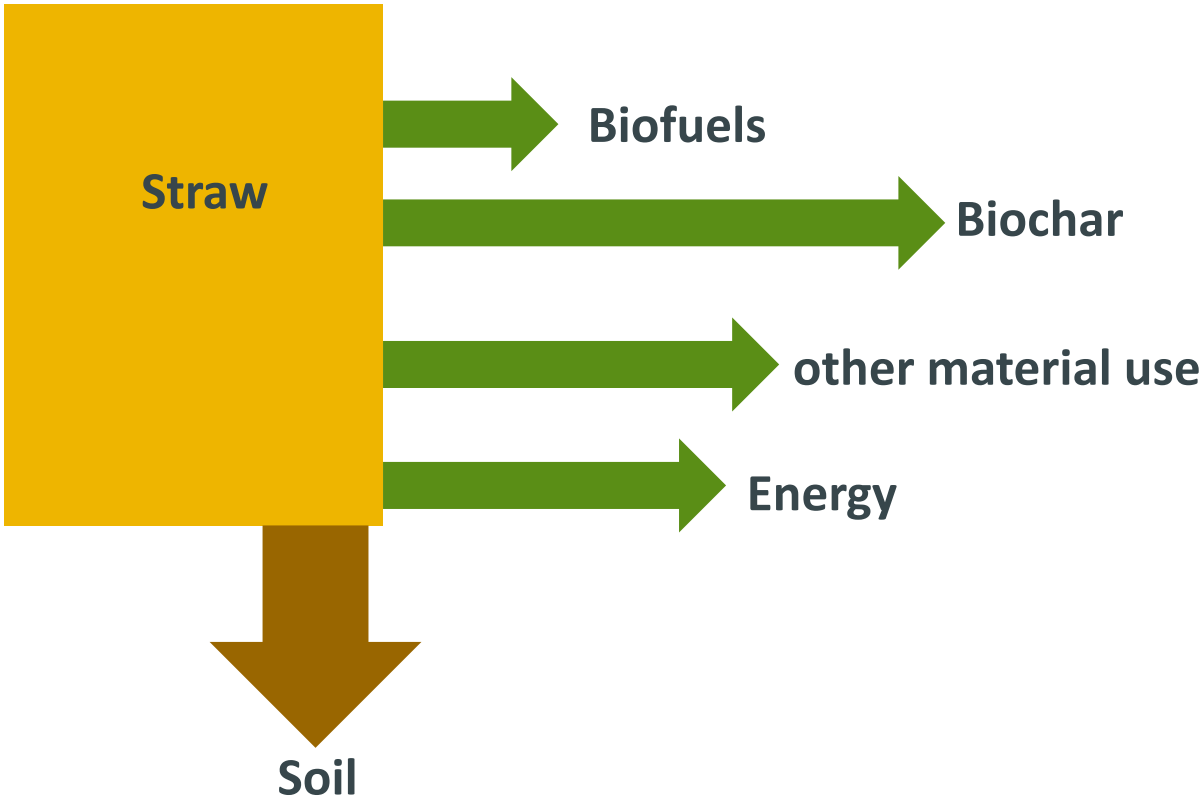
Roots are the key – not straw



- C input with roots determin the mean residence time (MRT) of soil C
- Differences in soil C between croplands and grasslands are explainable by root C input

Poeplau, Don *et al.* 2021, GCB

Alternatives uses for straw



Biochar potential of straw – case study Germany

36 Mio Mg straw a^{-1} (cereals, rape seed, maize) in Germany

5 Mio Mg straw a^{-1} = livestock bedding

12 Mio Mg straw a^{-1} = non-harvestable

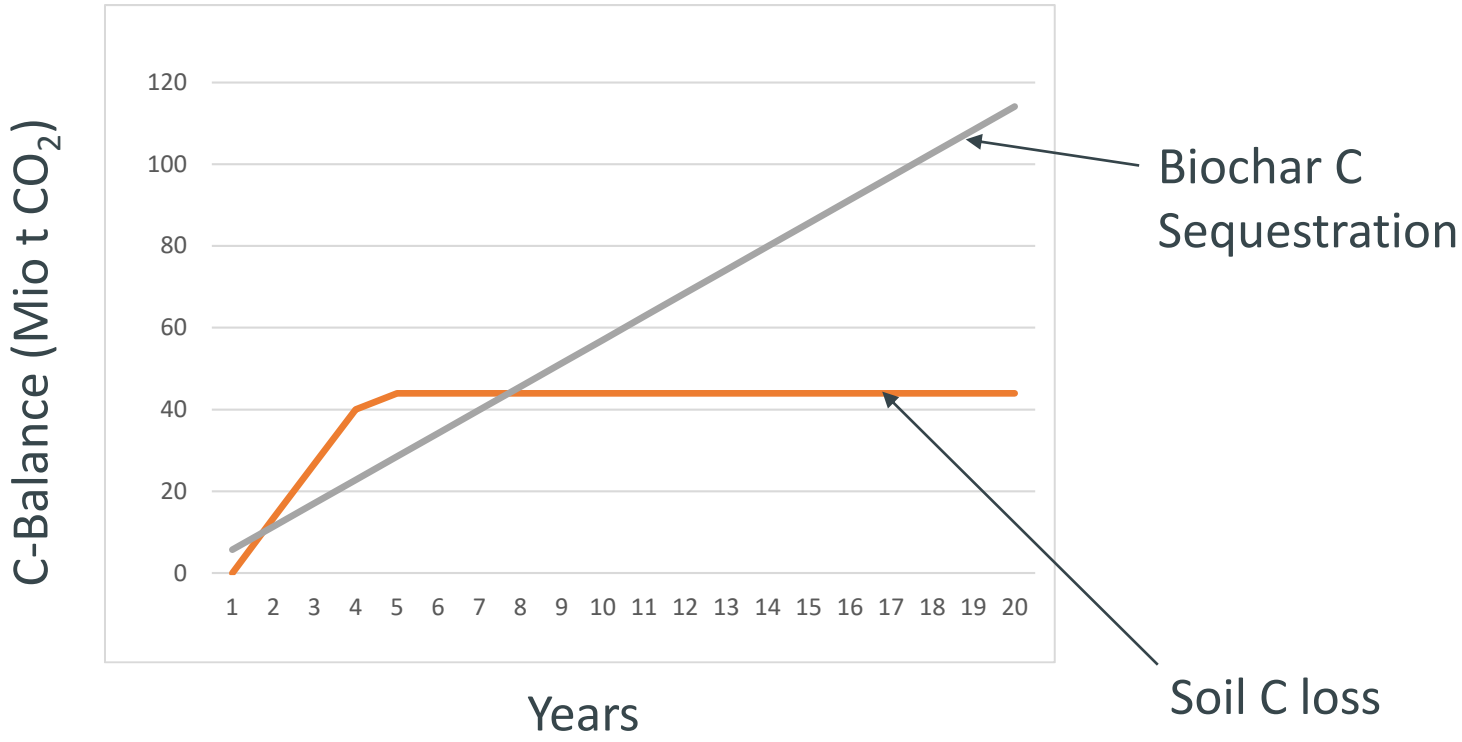
= 19 Mio t /a potential usable for biochar production

3 Mg straw per hectar would deliver around 0.3 Mg biochar ha^{-1}

This is a C sequestration of 1 Mg CO_2 ha^{-1}

Weiser et al. 2014,
Jacobs et al 2020,
Wang et al 2020

C balance of straw for biochar and soil-C



Biochar from straw is more climate friendly than soil C from straw

Fertilisation compensation

Straw removal of 3 Mg equals 18 kg N

CO_2 emissions for the production of 18 kg N-fertiliser:

66 kg CO_2

Formation of soil carbon: Shift in paradigm

Traditional knowledge:

Litter with wide C/N ratio has got lowest decomposition rates.

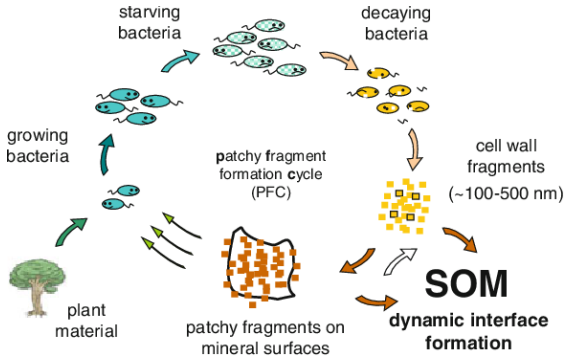
Thus, it contributes most to soil organic matter formation.

New knowledge:

Stabilised soil C is mostly microbial derived.

Microorganisms have an narrow C/N ratio.

Litter with narrow C/N ratio enhance microbial growth and thus contribute most to soil organic matter formation.



Miltner *et al.* 2012, Biogeochem.

Conclusions

- C-input to the soils is important to maintain and enhance soil carbon
- Root litter input is much more important than above ground litter such as straw
- Alternative uses for straw should be considered due to the low impact of straw removal on total soil carbon stocks.

Thank you for your attention!

axel.don@thuenen.de **www.thuenen.de/ak**

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