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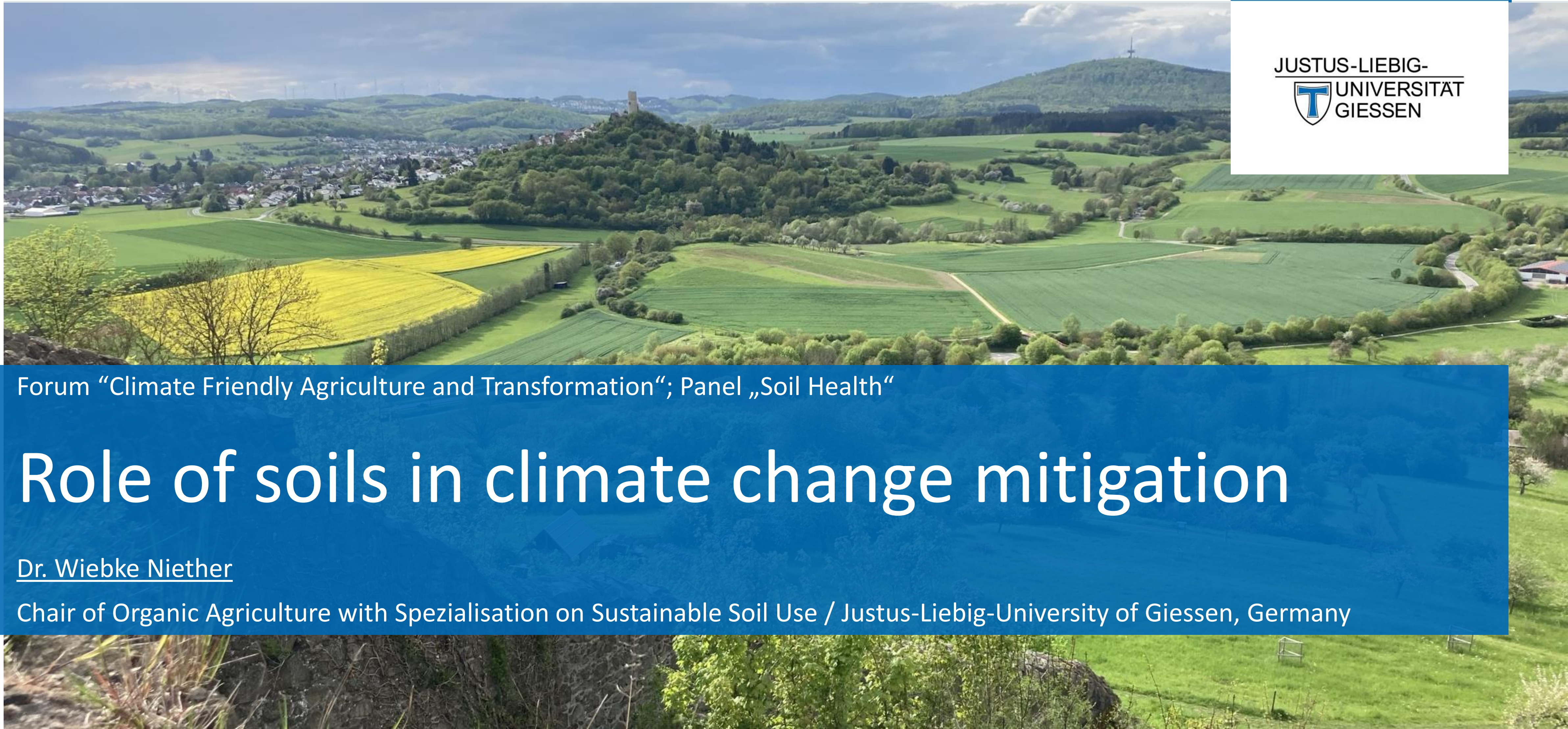


Forum “Climate Friendly Agriculture and Transformation“; Panel „Soil Health“

Role of soils in climate change mitigation

Dr. Wiebke Niether

Chair of Organic Agriculture with Spezialisation on Sustainable Soil Use / Justus-Liebig-University of Giessen, Germany

Pressure on agriculture and challenges: Heat and drought


Foto: Landkreis Marburg-Biedenkopf, 2022

Burning Landscapes


Pasture lacking fodder production


Foto: Oberhessische Zeitung, 2022

Dry river beds


Foto: Till Meinrenken, 2022

Reduced crop development

Pressure on agriculture and challenges: Rainstorm

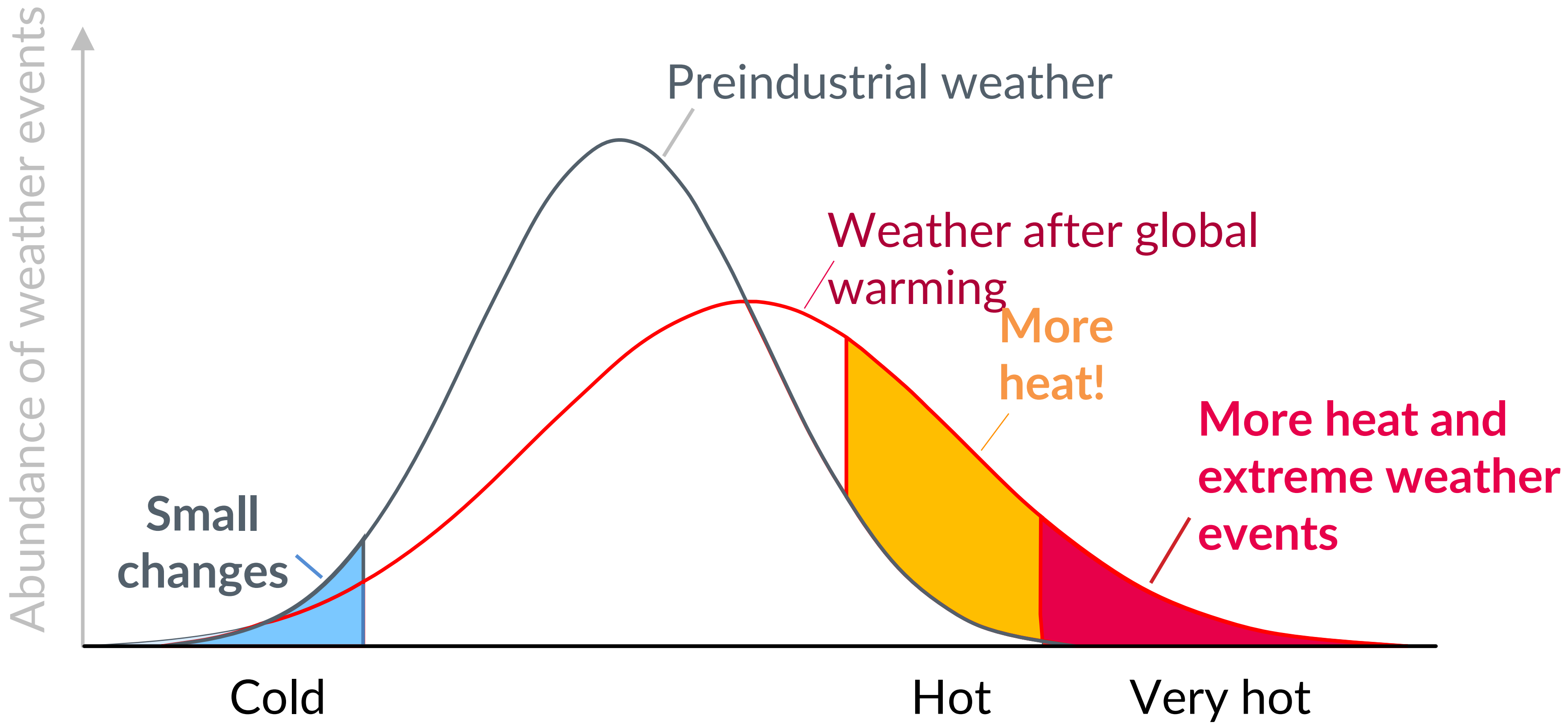
Destroyed crops

Erosion of arable land

Flooding

Conequential damage

Climate change induced extreme weather events



Emission reduction → climate protection

Principles

1. *Avoidance*
2. *Mitigation* → **Soils**
3. *Compensation*

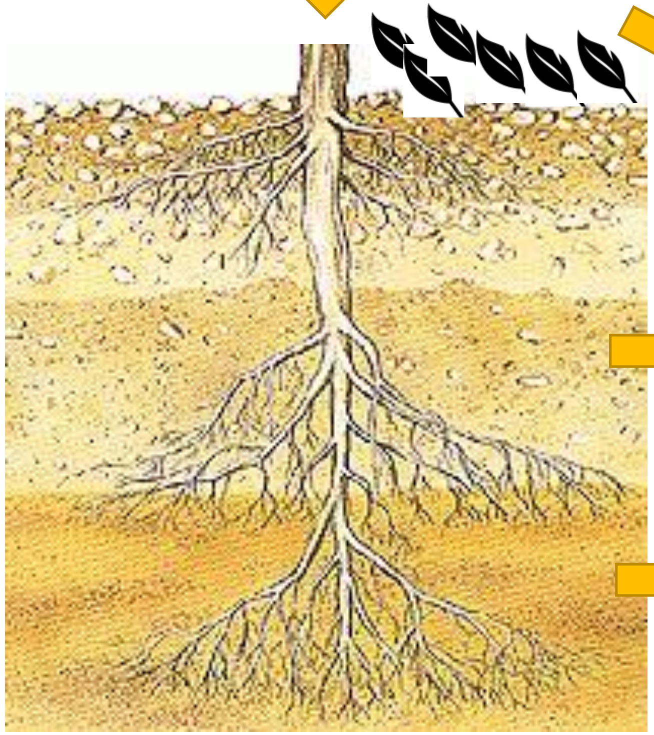
C-Sequestration potential

Croplands and grasslands on mineral soils	Absolute mitigation potential ($Mt\ CO_2e/year$)	Per hectare mitigation potential ($t\ CO_2e/ha/year$)
Global	200 - 1,000	0.2
EU	23 - 58	0.1 - 0.4
Germany	1.4	0.4

Frelih-Larsen et al. 2022

Soil organic matter formation and C sequestration

CO_2 – Uptake from athmosphere by crop photosynthesis



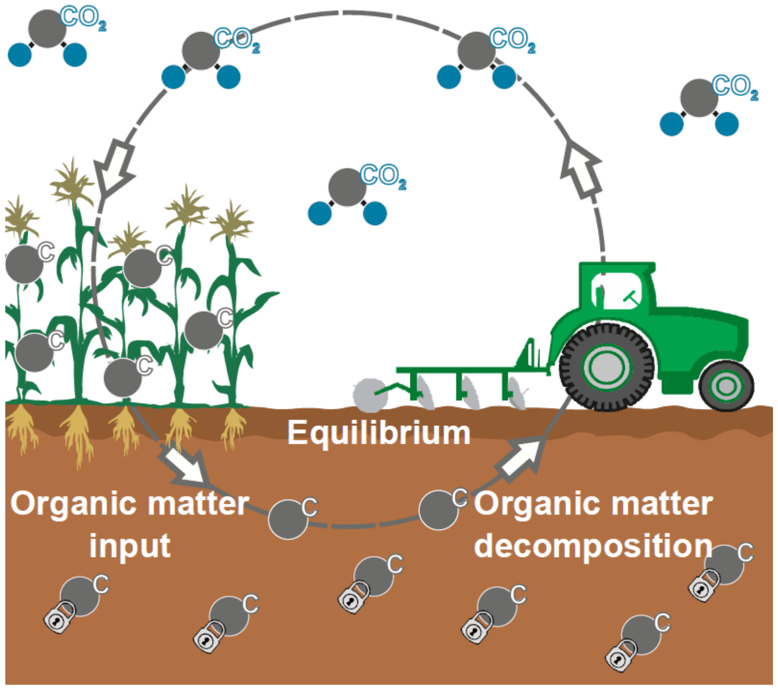
Organic Matter (OM) input:
Litter, crop residues, manure

Root-C: 2.3-times higher humus formation potential than C from litter or residues (Kätterer et al. 2011)

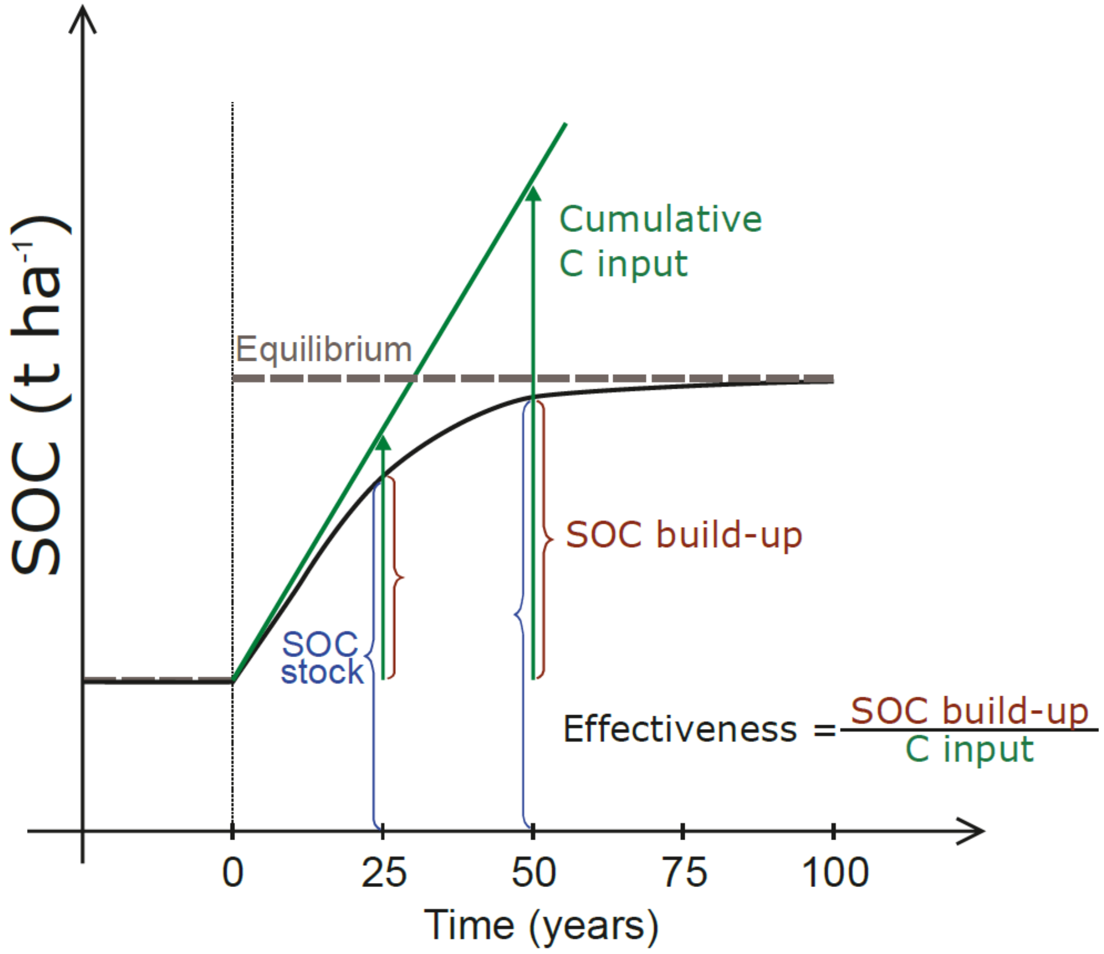
Root exsudates

Humus formation

Soil organic matter formation and C sequestration



Equilibrium of OM input and C degradation (C loss)
→ Soil aggregates seperate OM and decomposers
→ Stabilization of C by binding to clay minerals
→ Easy and difficult to degrade C compounds



$\text{Effectiveness}_{25\ \text{years}} >> \text{Effectiveness}_{50\ \text{years}}$

Wiesmeier et al., 2020

Nature based Solutions (NbS) for improving soil C sequestration

"locally appropriate, adaptive actions to protect, sustainably manage or restore natural or modified ecosystems in order to address targeted societal challenge(s) - such as climate change mitigation -, while simultaneously enhancing human well-being and providing biodiversity benefits"

(Reise et al. 2022)

Principles:

- **Nature friendly** → Beneficial for biodiversity, water bodies, soil biota…
- **Climate friendly** → Total climate impact (C-sequestration, CO_2, N_2O, CH_4), no leakage

Measures I

Measure	Type of measure[1]	NbS fit[2]	SOC sequestration potential (t CO_2e/ha/year)	Co-benefits vs. Trade-offs
Conversion arable to grassland	LC	0	0.6 - 3.3[3]	+++
Rewetting of organic soils	LC	++	1.5-1.6[4]	++
Silvoarable agroforestry	LC, MC	++	0.8 - 7.3 [5]	+++
Silvopastoral agroforestry	LC, MC	+++	0.3 - 27 [6]	+++
Mixed crop-livestock systems	MC, LC	+++	0.1[7]	++
Use of cover crops	MC	+++	0.3-1.1 [8]	+++
Crop rotations with forage legumes	MC	+++	2 - 2.4[9]	++
Crop rotation with grain legumes	MC	+++	No data	+++
Permanent grassland management	MC	+++	0.2-1[10]	++
Residue management	MC	+++	2.5[11]	+
Mulching	MC	++	No data.[12]	+
Applying manure / compost	MC	++	1.39[13]	++
Prevention of land take	LC	++	10 - 66%[14]	++

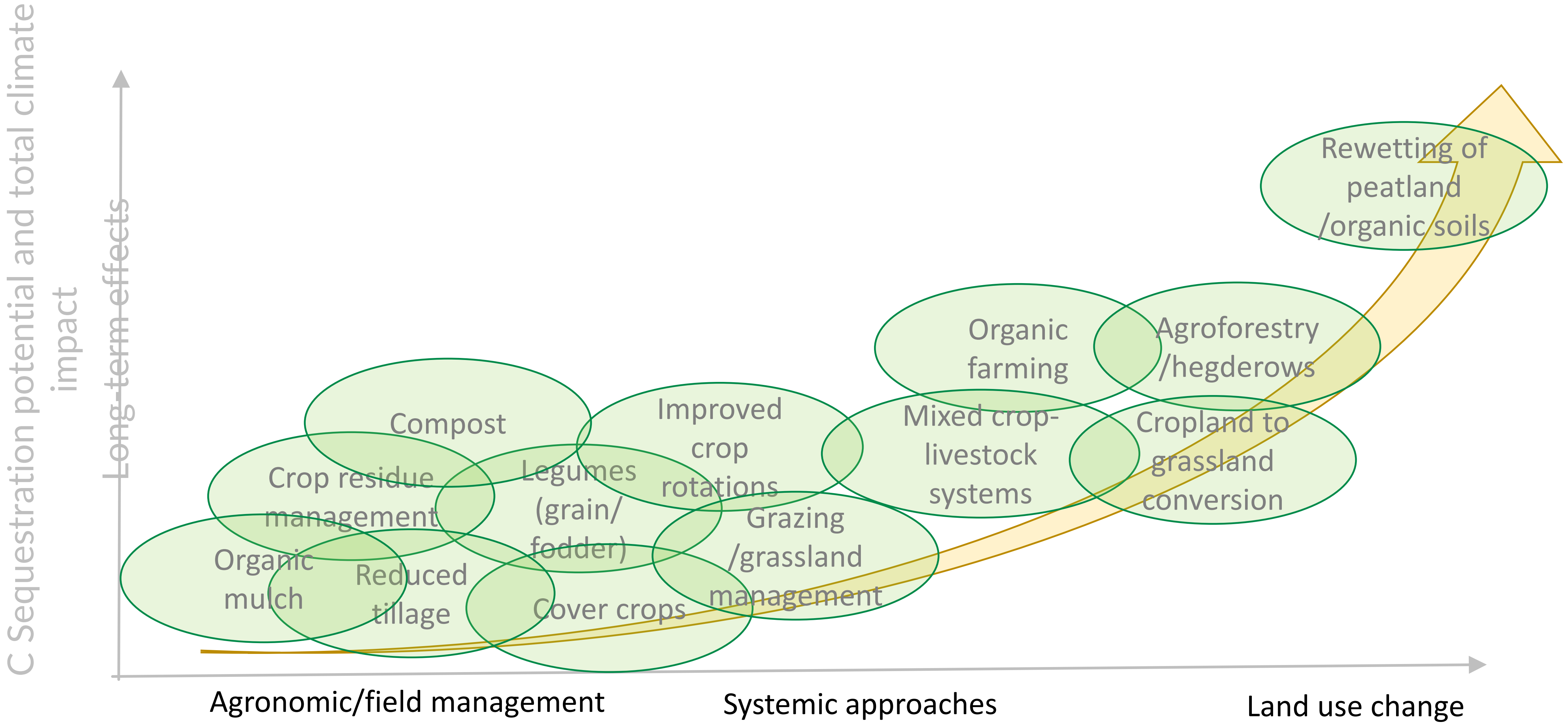
Frelih-Larsen et al. 2022

Measures II

Measure	Type of measure[1]	NbS fit[2]	SOC sequestration potential (t CO_2e/ha/year)	Co-benefits vs. Trade-offs
Improved crop rotation	MC	+++	0.2[15]	++
Buffer strips	MC	+++	7.2- 9.3[16]	++
Contour farming / terracing	MC	++	No data[17]	++
Reduction of compaction	MC	+++	No data	+
Nitrification inhibitors (biological / synthetic)	MC	Biological: +++ Synthetic: -	No data:[18]	-
Precision farming	MC	+	No data	++
Low input grasslands	MC	+++	0.14[19]	+
Organic farming	MC	+++	1.65	+++
Critical external inputs	MC	++	1.38[20]	++ / -

Frelih-Larsen et al. 2022

Improving soil C sequestration: from field level to landscape or territorial scale



Promoting climate friendly soil measures

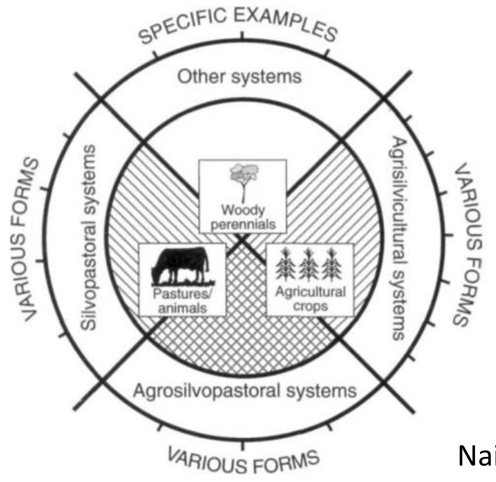
To be considered:

- Priorization of measures with high C sequestration potential (e.g. land use changes, land conversions)
- Systemic approaches (e.g. organic farming) can be legally difficult
- Prevention measures to maintain existing stocks (e.g. preventing land take, reducing compaction)
- C sequestration potential of soils is limited (equilibrium) → uncertainty and risk of reversal is high
- Application of external inputs can have mixed impacts on soil health / quality (e.g. use of nitrification inhibitors)
- Recognizing permanence (long term storage), leakage and saturation (equilibrium)
- Total climate impact + biodiversity and water and air quality

Agroforestry: agricultural system re-design

Use of the same area:

- Spatial /temporal synergies between components
- Fostering ecosystem services and functioning



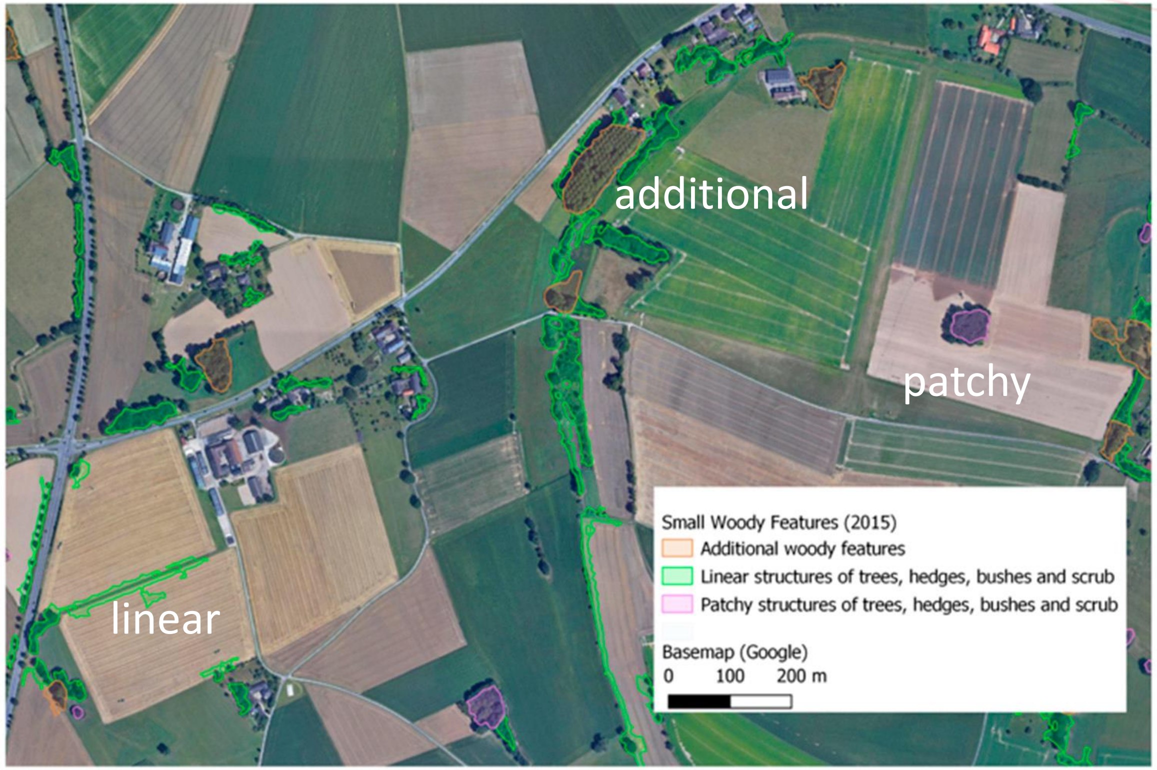
Nair et al. 1993

Pasture with trees or shrubs:
silvopastoral agroforestry system

Cropland with trees or shrubs:
silvoarable agroforestry system

Agroforestry: mitigation

Small woody landscape features (SWF) embedded within agricultural landscapes



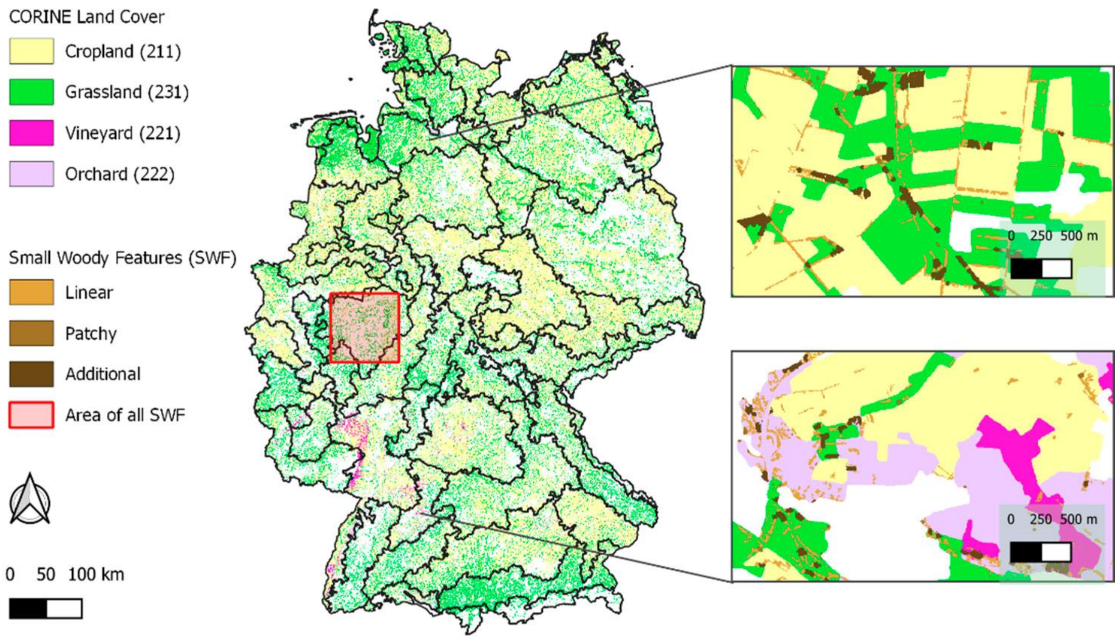
Addition to general calculations of above- and belowground carbon stocks:

→ total biomass carbon
→ soil organic carbon

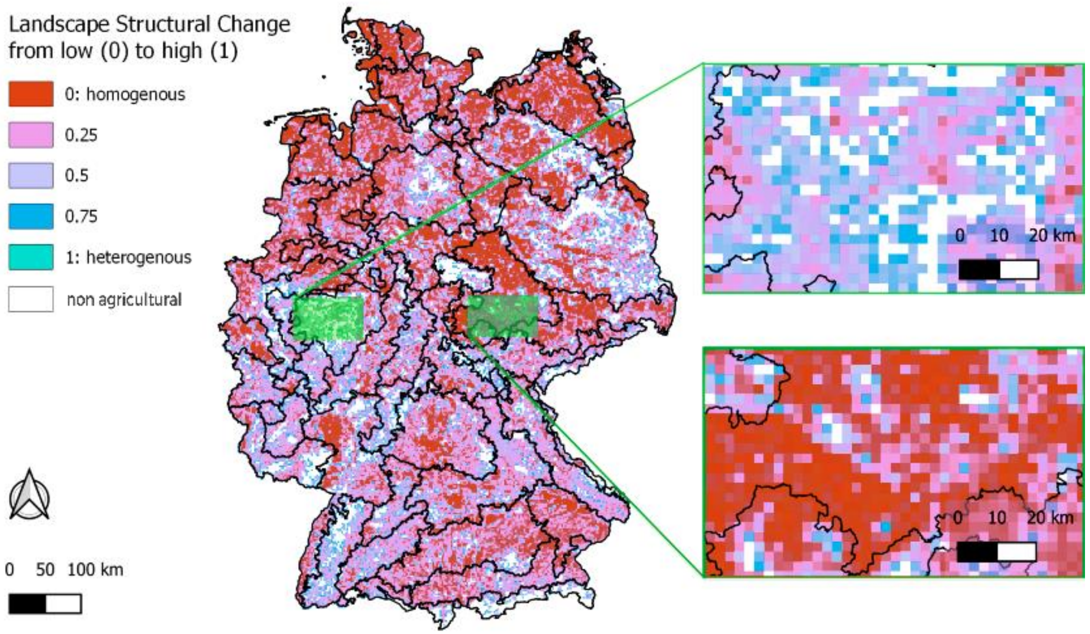
Golizc et al. 2021

Agroforestry: mitigation

Distribution of SWF across Germany



Landscape structural change arising from inclusion of small woody features



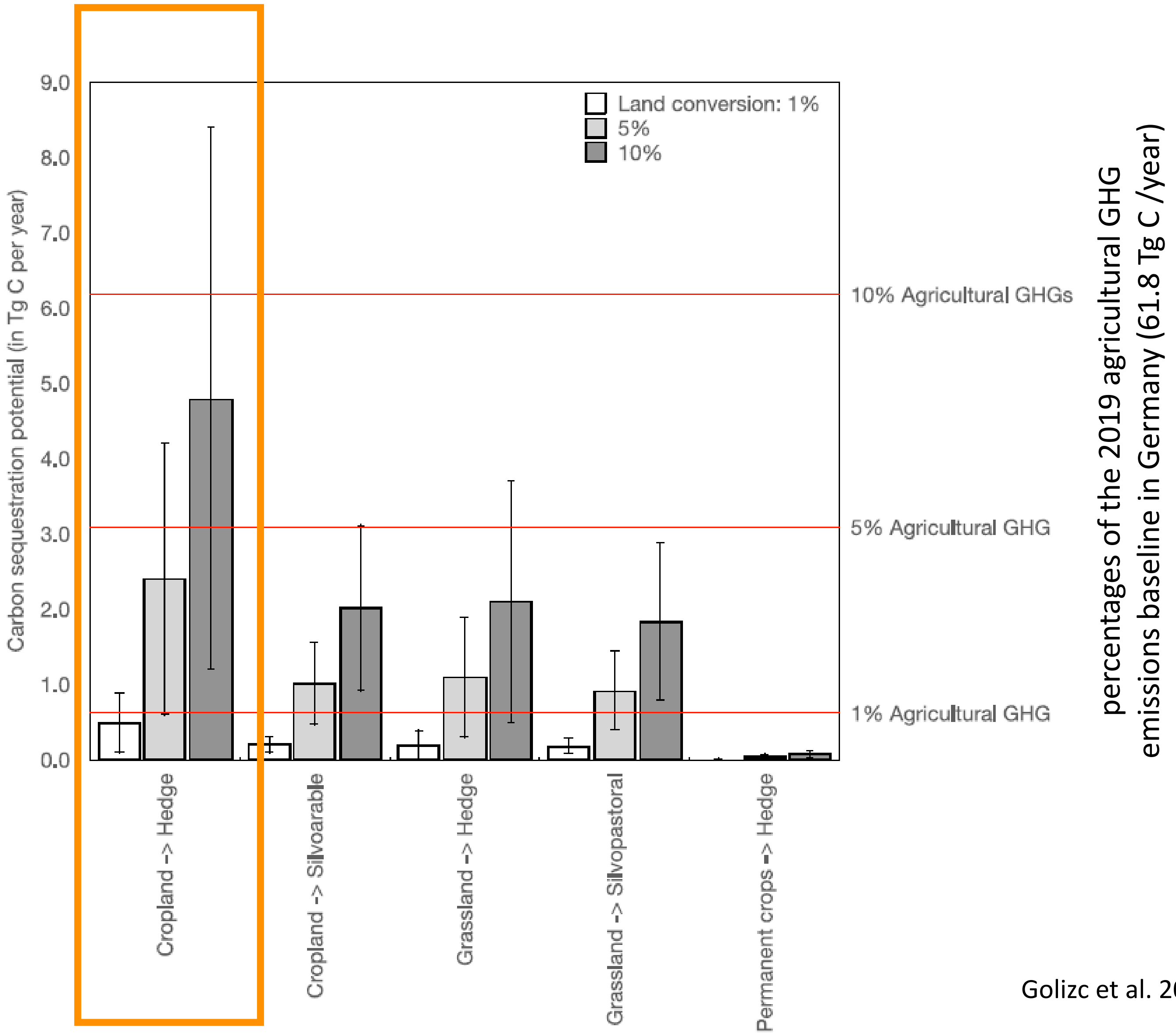
→ Increase in total biomass carbon
→ Increase in soil organic carbon (SOC)

Golizc et al. 2021

Agroforestry: mitigation

Potential of agroforestry implementation in German agriculture to sequester carbon:

3 scenarios:
- 1% land conversion to agroforestry
- 5% land conversion to agroforestry
- 10% land conversion to agroforetry



Golizc et al. 2021

Soil carbon → soil health → sustainable soil functioning

Soil quality / soil health:

- Productivity of soils including the **interactions of humans and soil**;
- Part of the environmental quality concept (beside water and air);
- Soil health → plant health → human health;
- Chemical, physical and biological (soil biota) approach → dynamic

Example of weighting of soil functions and associated indicators (Lima et al., 2013).

Soil function	Weight	Indicator level 1	Weight	Indicator level 2	Weight
Water infiltration, storage and supply	0.33	Available water	0.25		
		Mean weight diameter	0.25		
		Earthworms	0.25		
		Correlated indicators	0.25	Soil organic matter	0.50
				Bulk density	0.50
Nutrient storage, supply and cycling	0.33	Available water	0.25		
		Earthworms	0.25		
		Soil organic matter	0.25		
		Micronutrients	0.25	Manganese	0.33
				Copper	0.33
				Zn	0.33
Sustain biological activity	0.33	Soil organic matter	0.50		
		Earthworms	0.50		

Bünemann et al., 2018

Soil organic matter (soil C) plays a central role in soil functioning!

Soil functioning for sustainable production

«Conventional without C input»

«with C-input by compost»

Chemical properties: nutrient retention, soil fertility

(Mäder et al. 2002, Science)

Soil functioning for system resilience and sustainable production

The same soils after heavy rain event

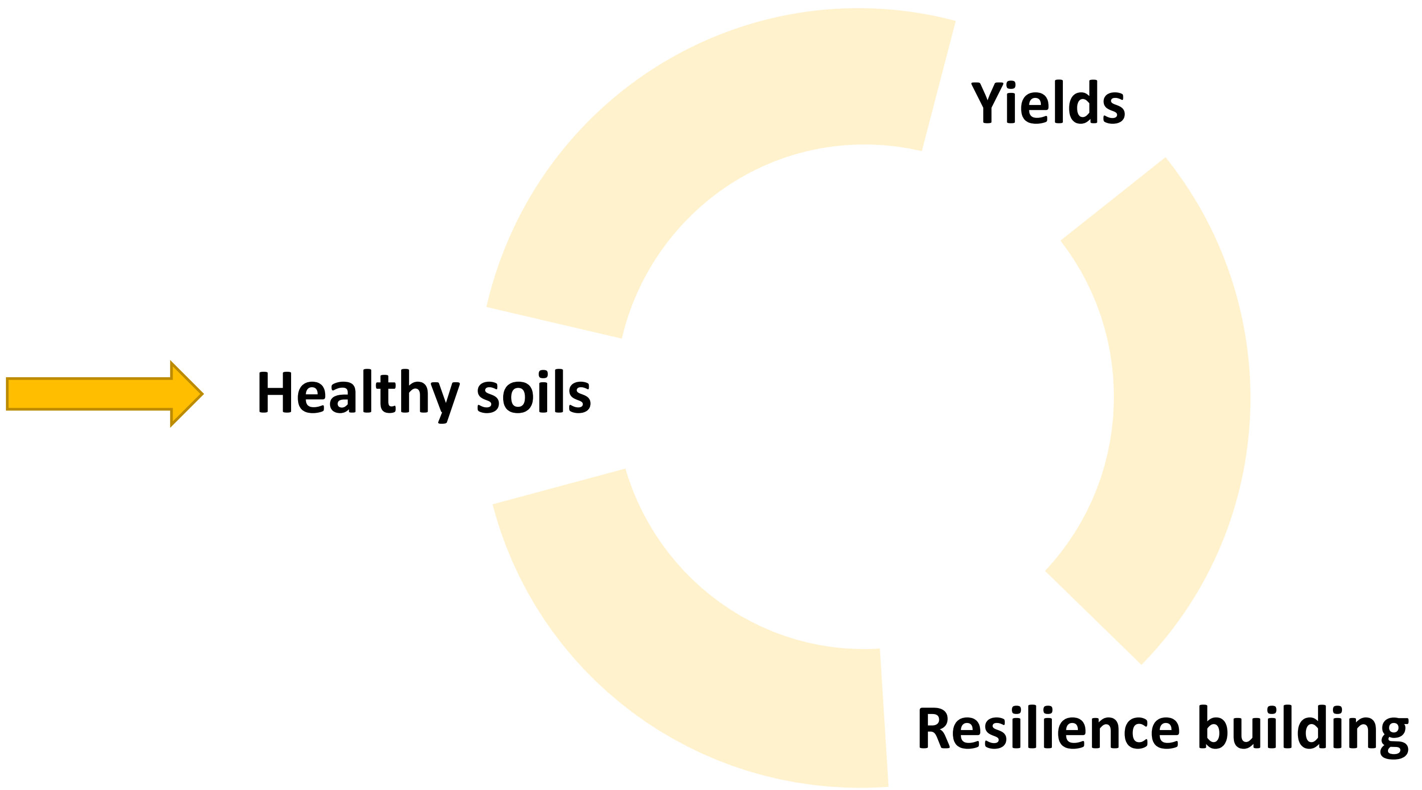
«Conventional without C input»

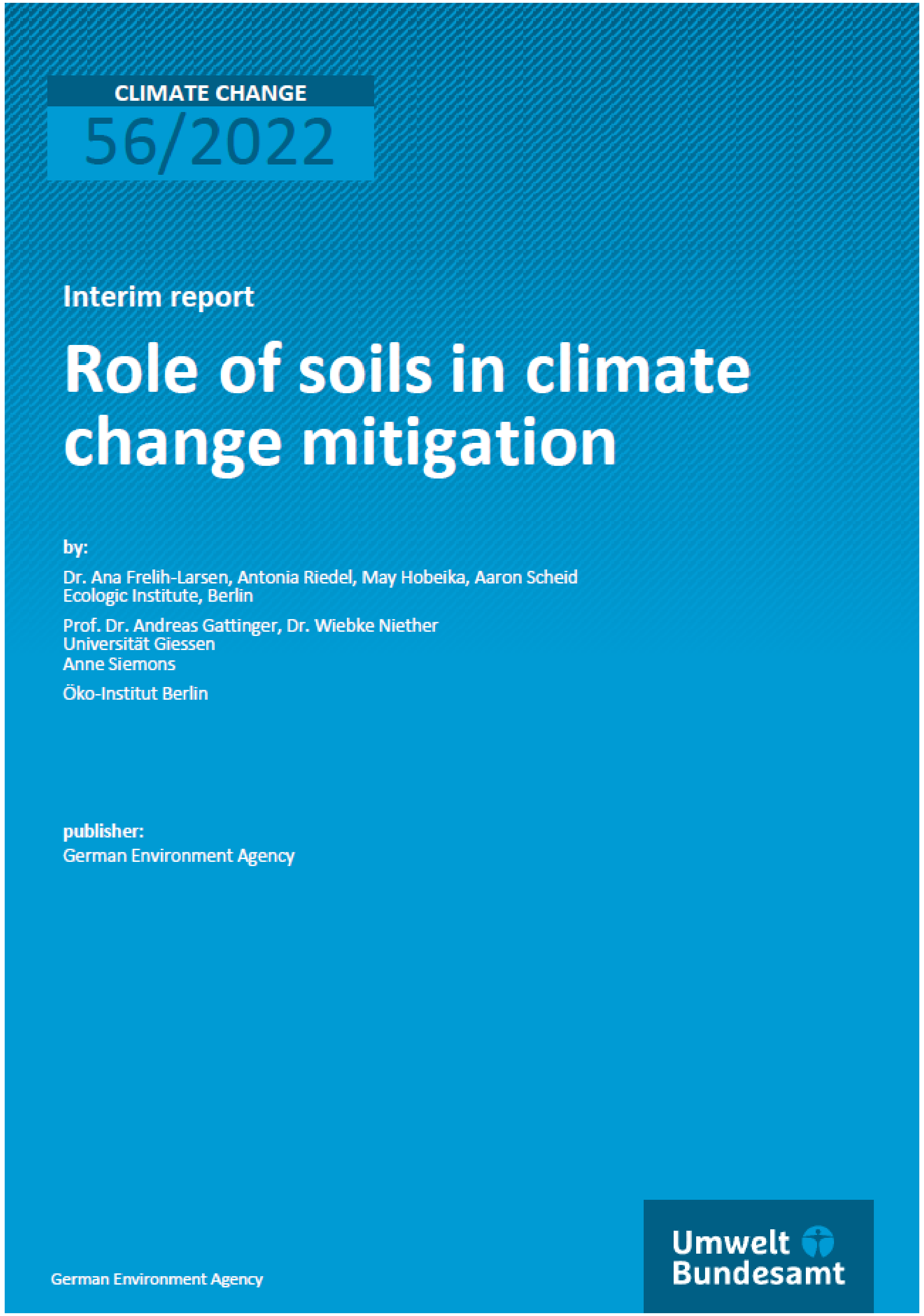
«with C-input by compost»

Physical properties: water infiltration, water retention

(Mäder et al. 2002, Science)

„The soil is the base“ (Schreefel et al. 2020)
→ Building resilience and maintaining yields





CLIMATE CHANGE 56/2022

Interim report

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by:

Dr. Ana Frelih-Larsen, Antonia Riedel, May Hobeika, Aaron Scheid
Ecologic Institute, Berlin

Prof. Dr. Andreas Gattinger, Dr. Wiebke Niether
Universität Giessen
Anne Siemons

Öko-Institut Berlin

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Thank you for your attention

Contact: wiebke.niether@agrar.uni-giessen.de

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