

# Carbon contents and stocks in organically managed soils



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# Agenda

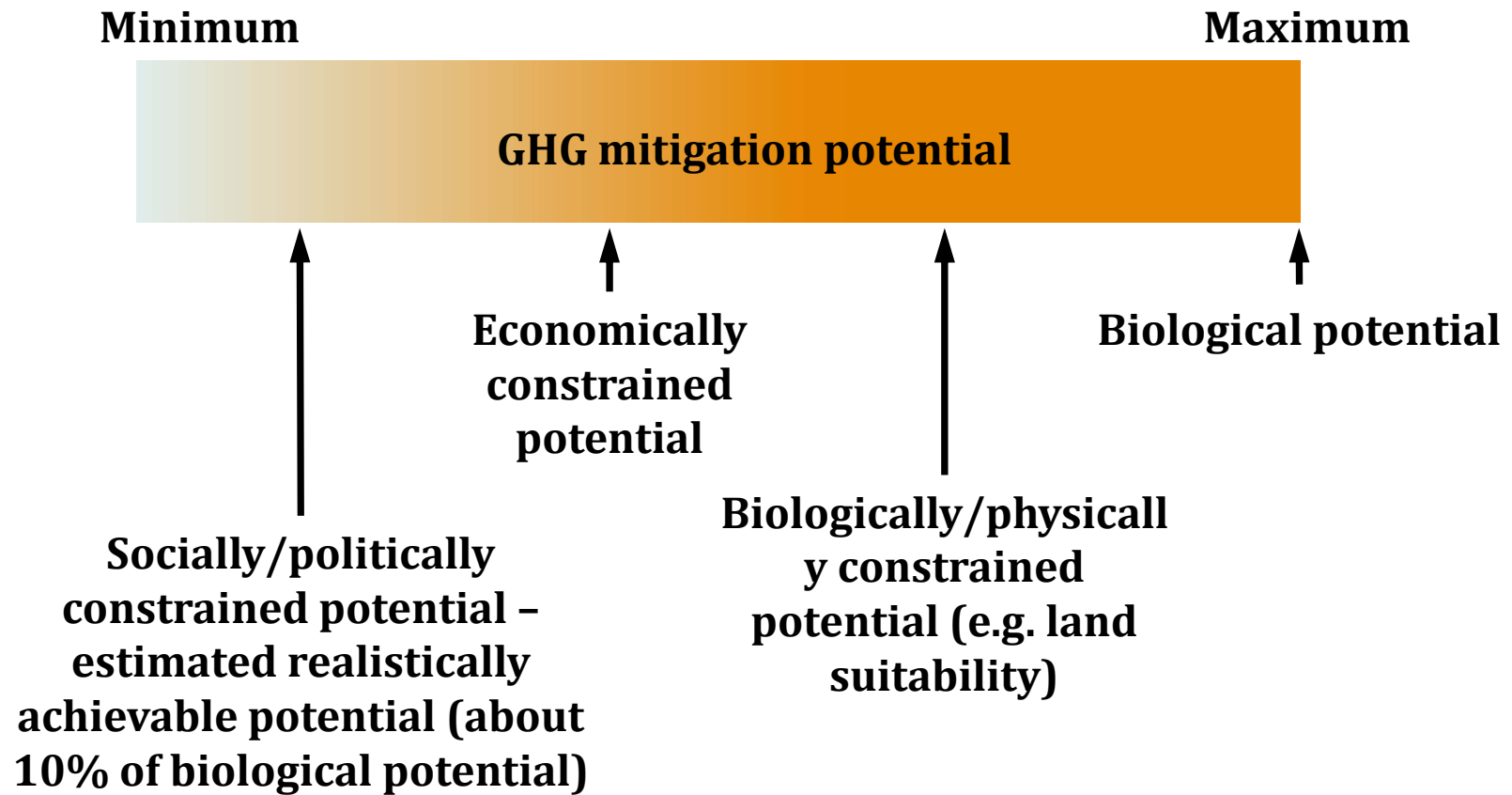
- 1. Introduction**
- 2. First results from a meta study**
- 3. Challenges for quantification**

# Three Ways to Mitigate Climate Change

According to the IPCC (WG III, 2007):

- Reducing emissions in agriculture (e.g. fertilizer optimization)
- **Enhancing GHG removal through management (e.g. zero-tillage, conservation tillage; conserve/increase soil C pools)**
- Avoiding emissions (e.g. bio-energy...)

# Mitigation Potential is Constrained



Sources: adapted by Smith et al. 2005 (page 2154)

# Organic Agriculture: Higher Potential to Mitigate

**According to Niggli et al. (2009):**

- Organic farming with its two current priorities - improving and integrating crop and animal production under low-external-input environments and selecting varieties and breeds especially for these conditions - can cope with several of the mentioned recommendations simultaneously.

**However: Issues:**

- No coherent data and estimates of carbon sequestration of organically farmed soils are currently available.
- Data availability seems to be very limited, not enough studies done.
- Geoclimatic heterogeneity is not accounted for.

# Objectives/Approaches

*Objective:*

***Analysis of carbon sequestration potential in organic farming in Switzerland and neighbouring regions.***

*Two Approaches:*

› **1) Carbon Stocks:**

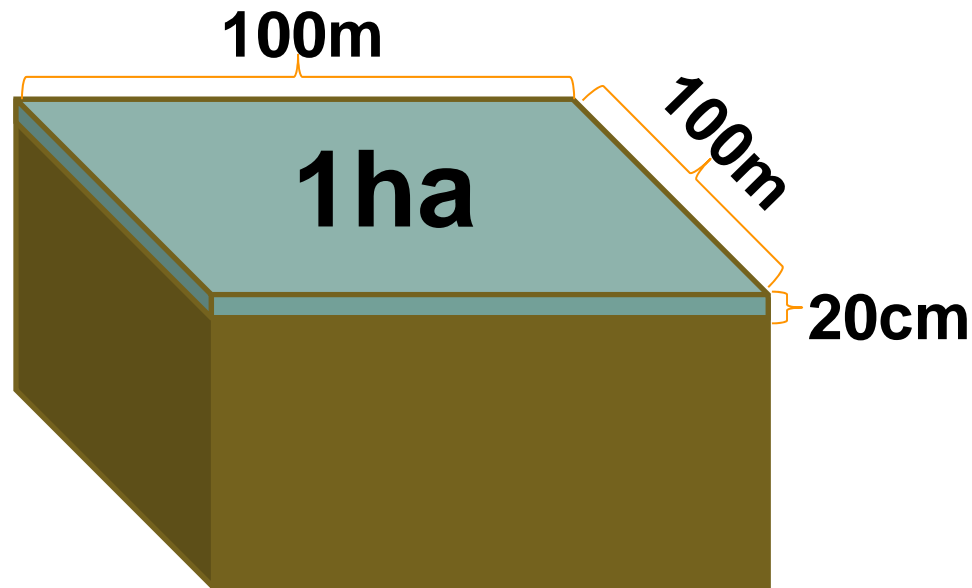
- › *Organically farmed soils in Switzerland contain higher carbon stocks than conventionally farmed soils.*
- › *→ Preliminary Results 1*

› **2) Soil Organic Carbon:**

- › *Organically farmed soils in Switzerland contain higher amounts of soil organic carbon (SOC) than conventionally farmed soils.*
- › *→ Preliminary Results 2*

**To find answers, we chose the tool of a meta-analysis.**

# How Carbon Stocks are Calculated



*carbon stock (t/ha) =*

$$10 \bullet \text{soil organic carbon (g/kg)} \bullet \text{bulk density (t/m}^3\text{)} \bullet \text{depth (m)}$$

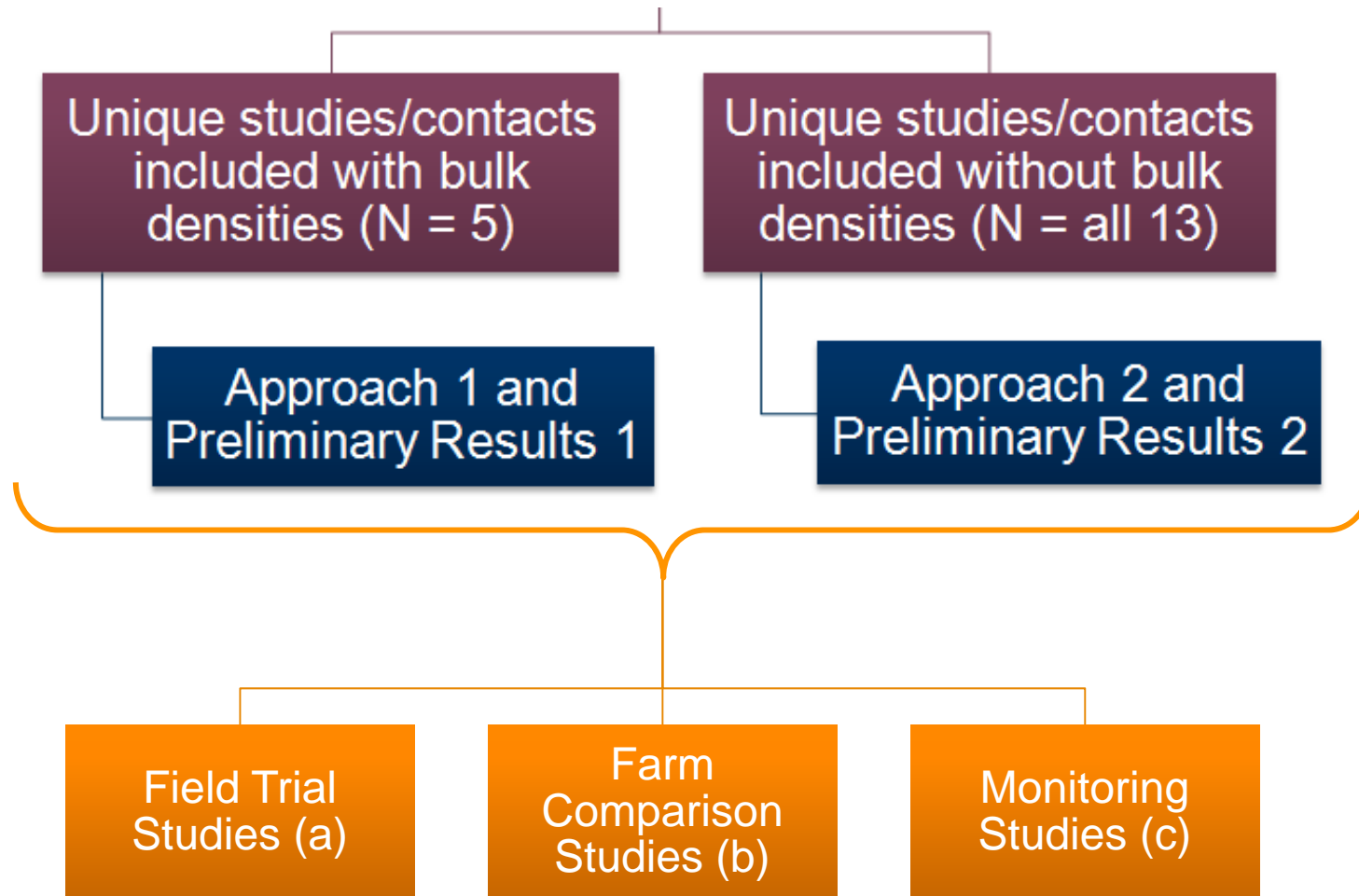




# Flow Chart: Selection of Studies

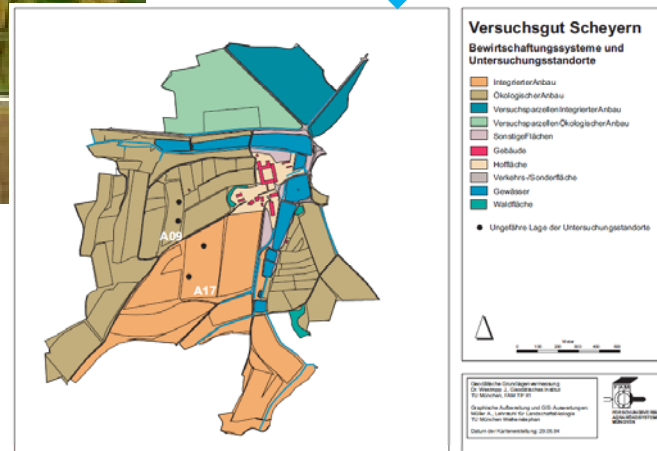
Level	Included	Excluded	Reason for Excluding
1) Total	> 800	--	Not containing carbon data
2) Selected for Evaluation	> 512	> 300	Not directly addressing the issues
			Older than 30 years
			Not within Switzerland and/or close neighbouring regions
3) Retrieved and Included	183	329	Redundant and forwarded contacts
			Non representative farm practices
			Not containing livestock/animals
4) Found or Answered	91	92	Not found or answered after contacting at least three times within time period at hand
			Redundant/multiply published
5) Analysed and Included	5	86	Containing bulk densities

# Categories of Data



# Studies Included for Approach 1

Name	Field Trial DOK	Field Trial Scheyern (Sehy)	KABO Bern Monitoring
Location	Therwil, Switzerland	Scheyern, Germany	Canton of Bern, Switzerland
Authors	FiBL and ART	U. Sehy (Dissertation)	Bodenschutzfachstelle Canton of Bern (A. Chervet et al.)



# ***Carbon stocks: Meta-Analysis***

Study name

Field Trial DOK, Therwil  
Field Trial DOK, Therwil  
Field Trial DOK, Therwil  
KABO Bern (Monitoring)  
Field Trial DOK, Therwil  
Field Trial Scheyern  
KABO Bern (Monitoring)  
Field Trial Scheyern  
Field Trial Scheyern  
Field Trial Scheyern

# Carbon stocks: Meta-Analysis

Study name	Subgroup within study
Field Trial DOK, Therwil	CRP1
Field Trial DOK, Therwil	CRP2
Field Trial DOK, Therwil	CRP3
KABO Bern (Monitoring)	Before 2000
Field Trial DOK, Therwil	CRP4
Field Trial Scheyern	Year 1999
KABO Bern (Monitoring)	After 1999
Field Trial Scheyern	Year 2000
Field Trial Scheyern	Year 2001
Field Trial Scheyern	Year Unspecified

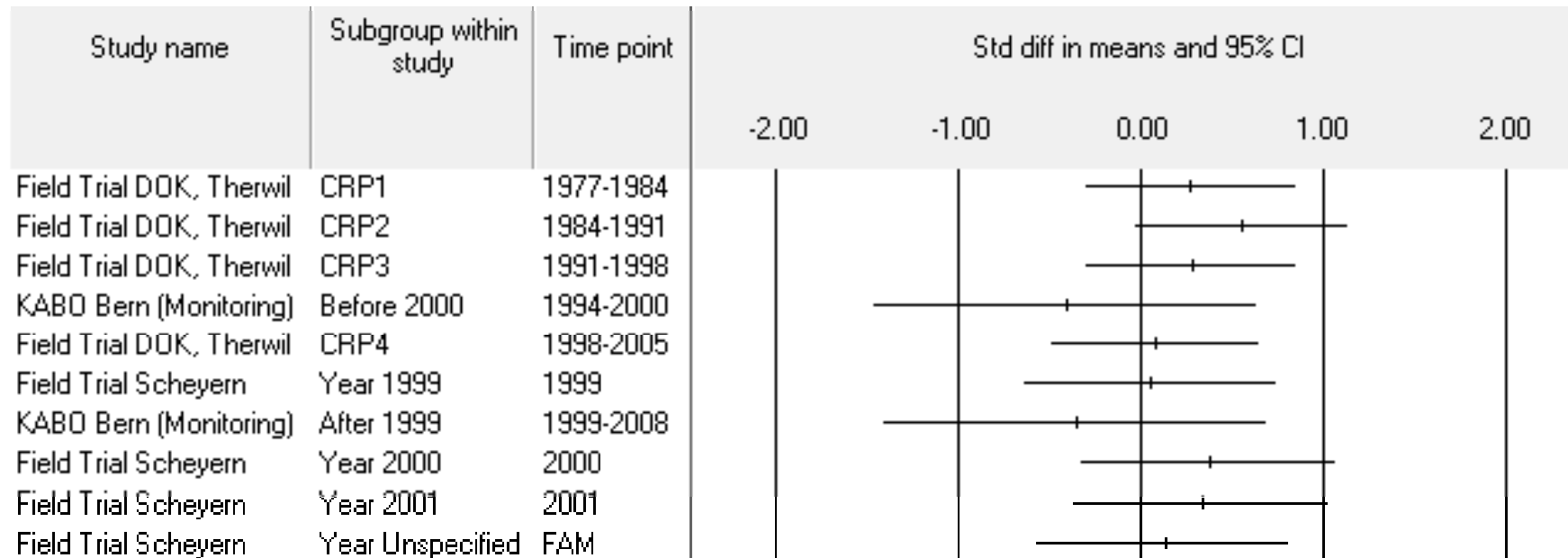
# Carbon stocks: Meta-Analysis

Study name	Subgroup within study	Time point
Field Trial DOK, Therwil	CRP1	1977-1984
Field Trial DOK, Therwil	CRP2	1984-1991
Field Trial DOK, Therwil	CRP3	1991-1998
KABO Bern (Monitoring)	Before 2000	1994-2000
Field Trial DOK, Therwil	CRP4	1998-2005
Field Trial Scheyern	Year 1999	1999
KABO Bern (Monitoring)	After 1999	1999-2008
Field Trial Scheyern	Year 2000	2000
Field Trial Scheyern	Year 2001	2001
Field Trial Scheyern	Year Unspecified	FAM

# Carbon stocks: Meta-Analysis

Study name	Subgroup within study	Time point	Statistics for each study						
			Std diff in	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Field Trial DOK, Therwil	CRP1	1977-1984	0.270	0.293	0.086	-0.304	0.845	0.921	0.357
Field Trial DOK, Therwil	CRP2	1984-1991	0.559	0.297	0.088	-0.024	1.142	1.880	0.060
Field Trial DOK, Therwil	CRP3	1991-1998	0.278	0.293	0.086	-0.296	0.853	0.950	0.342
KABO Bern (Monitoring)	Before 2000	1994-2000	-0.405	0.537	0.288	-1.457	0.647	-0.754	0.451
Field Trial DOK, Therwil	CRP4	1998-2005	0.085	0.292	0.085	-0.488	0.657	0.290	0.772
Field Trial Scheyern	Year 1999	1999	0.058	0.354	0.125	-0.635	0.751	0.164	0.870
KABO Bern (Monitoring)	After 1999	1999-2008	-0.359	0.536	0.288	-1.410	0.693	-0.669	0.504
Field Trial Scheyern	Year 2000	2000	0.375	0.356	0.127	-0.324	1.073	1.051	0.293
Field Trial Scheyern	Year 2001	2001	0.336	0.356	0.127	-0.362	1.033	0.943	0.345
Field Trial Scheyern	Year Unspecified	FAM	0.129	0.354	0.125	-0.564	0.823	0.365	0.715

# Carbon stocks: Meta-Analysis





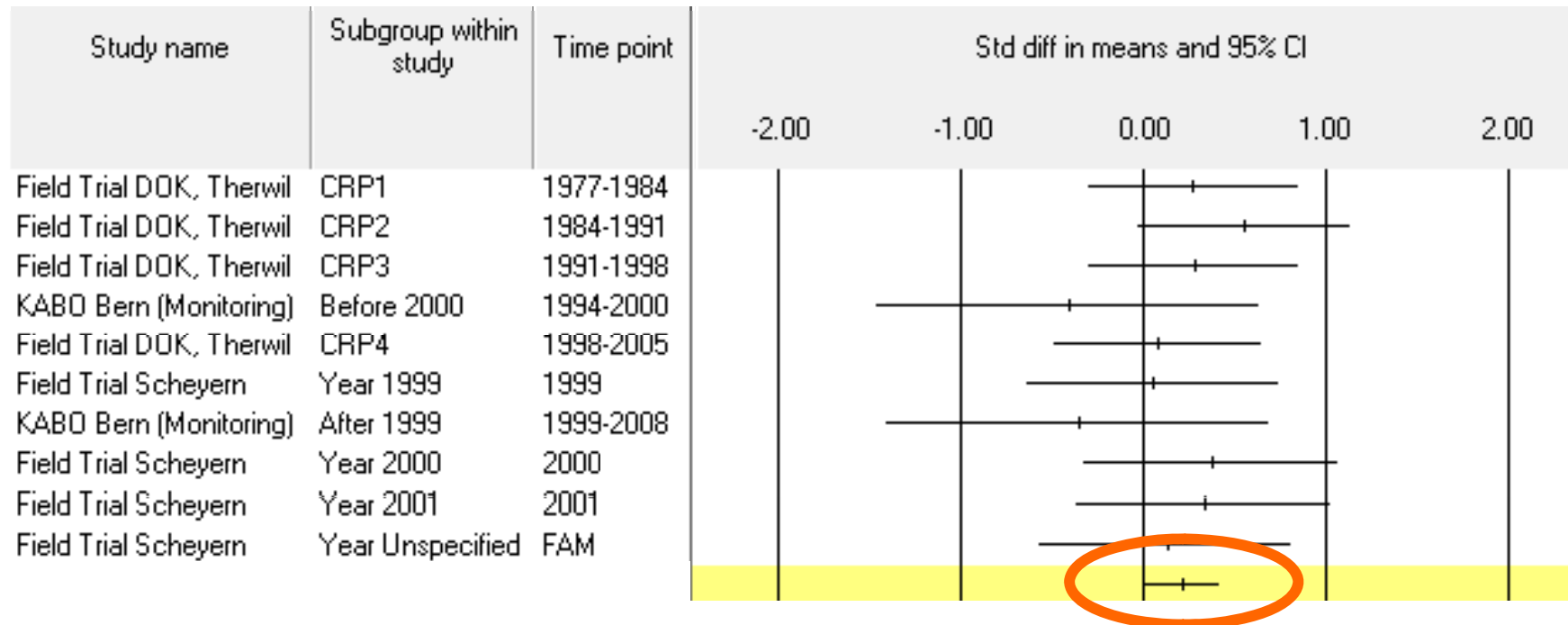
# Carbon stocks: Meta-Analysis

Study name	Subgroup within study	Time point	Weight (Fixed)		Residual (Fixed)		Sample size	
			Relative weight		Std Residual		Organic	Conventional
Field Trial DOK, Therwil	CRP1	1977-1984	13.69		0.21		24	23
Field Trial DOK, Therwil	CRP2	1984-1991	13.30		1.25		24	23
Field Trial DOK, Therwil	CRP3	1991-1998	13.68		0.24		24	23
KABO Bern (Monitoring)	Before 2000	1994-2000	4.08		-1.18		4	28
Field Trial DOK, Therwil	CRP4	1998-2005	13.80		-0.48		24	23
Field Trial Scheyern	Year 1999	1999	9.41		-0.46		12	24
KABO Bern (Monitoring)	After 1999	1999-2008	4.09		-1.09		4	28
Field Trial Scheyern	Year 2000	2000	9.27		0.48		12	24
Field Trial Scheyern	Year 2001	2001	9.29		0.36		12	24
Field Trial Scheyern	Year Unspecified	FAM	9.39		-0.25		12	24

# Carbon stocks: Meta-Analysis

Study name	Subgroup within study	Time point	Statistics for each study						
			Std diff in	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Field Trial DOK, Therwil	CRP1	1977-1984	0.270	0.293	0.086	-0.304	0.845	0.921	0.357
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KABO Bern (Monitoring)	Before 2000	1994-2000	-0.405	0.537	0.288	-1.457	0.647	-0.754	0.451
Field Trial DOK, Therwil	CRP4	1998-2005	0.085	0.292	0.085	-0.488	0.657	0.290	0.772
Field Trial Scheyern	Year 1999	1999	0.058	0.354	0.125	-0.635	0.751	0.164	0.870
KABO Bern (Monitoring)	After 1999	1999-2008	-0.359	0.536	0.288	-1.410	0.693	-0.669	0.504
Field Trial Scheyern	Year 2000	2000	0.375	0.356	0.127	-0.324	1.073	1.051	0.293
Field Trial Scheyern	Year 2001	2001	0.336	0.356	0.127	-0.362	1.033	0.943	0.345
Field Trial Scheyern	Year Unspecified	FAM	0.129	0.354	0.125	-0.564	0.823	0.365	0.715
			0.213	0.108	0.012	0.001	0.426	1.968	0.049

# Carbon stocks: Meta-Analysis



# Objectives/Approaches

## *Two Approaches:*

### › **1) Carbon Stocks:**

- › *Organically farmed soils in Switzerland contain higher carbon stocks than conventionally farmed soils: 37.4 vs 37.0 t C/ha*

*However 1:*

- › *Basic statistical analysis shows (time line and box plots):*

- › *Unevenly distributed data*

- › *Meta-analysis (funnel plots) shows:*

- › *Heterogeneity*

- › *Some publication bias*

### › **2) Soil Organic Carbon:**

- › *Organically farmed soils in Switzerland contain higher amounts of soil organic carbon (SOC) than conventionally farmed soils.*

- › *→ Preliminary Results 2*

# Objectives/Approaches

## *Two Approaches:*

### ➤ **1) Carbon Stocks:**

- *Organically farmed soils in Switzerland contain higher carbon stocks than conventionally farmed soils: 37.4 vs 37.0 t C/ha*
- *However 1:*
- *Basic statistical analysis shows (time line and box plots):*
  - *Unevenly distributed data*
- *Meta-analysis (funnel plots) shows:*
  - *Heterogeneity*
  - *Some publication bias*

### ➤ **2) Soil Organic Carbon:**

- *Organically farmed soils in Switzerland contain higher amounts of soil organic carbon (SOC) than conventionally farmed soils.*
- *→ Preliminary Results 2*

# Objectives/Approaches

## *Two Approaches:*

### › **1) Carbon Stocks:**

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### › **2) Soil Organic Carbon:**

- › *Organically farmed soils in Switzerland contain higher amounts of soil organic carbon (SOC) than conventionally farmed soils.*

- › *→ Preliminary Results 2*

# Carbon contents: Meta-Analysis (Part 2)

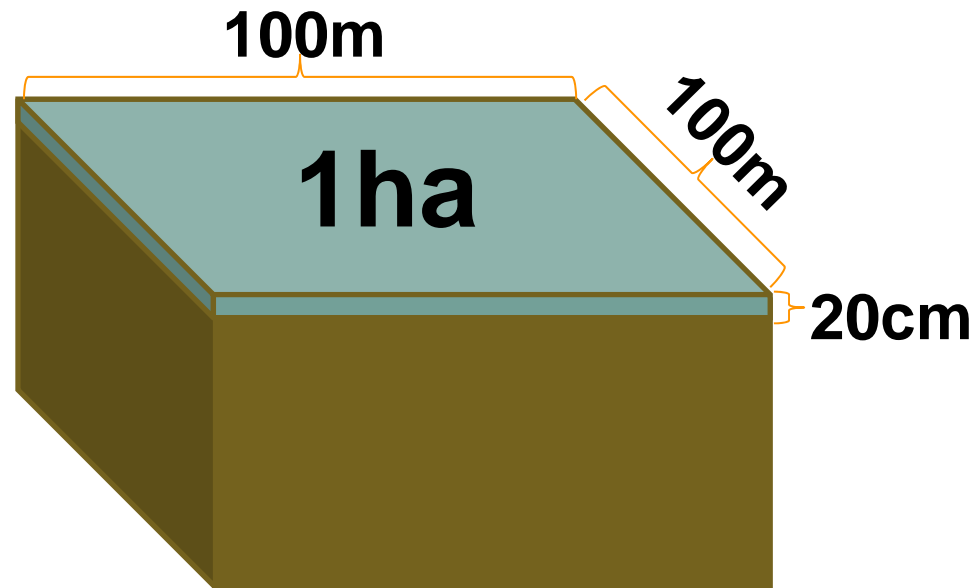
Study name	Subgroup within study	Statistics for each study						
		Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Field Trial Burgrain	1998, 0-20cm	-0.109	0.250	0.063	-0.600	0.381	-0.438	0.662
Field Trial DOK, Therwil	1999, 0-20cm	0.402	0.292	0.085	-0.170	0.973	1.378	0.168
Brunner et al. (Farm Comparison)	1999, 0-20cm	0.229	0.289	0.084	-0.338	0.796	0.792	0.428
KABO Bern (Monitoring)	1999-2006, 0-20cm	-0.390	0.759	0.576	-1.878	1.098	-0.514	0.607
Field Trial DOK, Therwil	2000, 0-20cm	0.261	0.290	0.084	-0.307	0.829	0.901	0.367
Field Trial Scheyern (Sehy)	2000, 0-20cm	-0.023	0.354	0.125	-0.716	0.670	-0.066	0.947
Field Trial Burgrain	2000, 0-20cm	0.084	0.250	0.063	-0.406	0.574	0.337	0.736
Field Trial DOK, Therwil	2001, 0-20cm	0.183	0.289	0.084	-0.384	0.750	0.632	0.528
KABO St. Gallen (Monitoring)	2001, 0-20cm	0.102	0.188	0.035	-0.267	0.471	0.540	0.589
Field Trial DOK, Therwil	2002, 0-20cm	0.362	0.291	0.085	-0.209	0.932	1.243	0.214
Field Trial Burgrain	2002, 0-20cm	0.064	0.250	0.063	-0.426	0.554	0.255	0.799
Field Trial DOK, Therwil	2003, 0-20cm	0.244	0.290	0.084	-0.324	0.811	0.841	0.401
Field Trial DOK, Therwil	2004, 0-20cm	0.091	0.289	0.083	-0.475	0.657	0.316	0.752
Field Trial Burgrain	2004, 0-20cm	0.086	0.354	0.125	-0.607	0.779	0.242	0.808
Field Trial DOK, Therwil	2005, 0-20cm	0.385	0.291	0.085	-0.186	0.956	1.323	0.186
KABO St. Gallen (Monitoring)	2006, 0-20cm	0.251	0.377	0.142	-0.488	0.990	0.665	0.506
Field Trial MASCOT	2006, 0-25cm	0.891	0.428	0.183	0.052	1.730	2.082	0.037
KABO Aargau (Monitoring)	2006, 0-20cm	-0.106	0.746	0.556	-1.567	1.355	-0.142	0.887
Field Trial Burgrain	2006, 0-20cm	0.054	0.354	0.125	-0.639	0.747	0.152	0.879
		0.163	0.050	0.003	0.065	0.261	3.259	0.001

# Carbon contents: Meta-Analysis (Part 2)

Study name	Subgroup within study	Weight (Fixed)		Residual (Fixed)	
		Relative weight	2.00	Std Residual	2.00
Field Trial Burgrain	1998, 0-20cm	24	48		
Field Trial DOK, Therwil	1999, 0-20cm	24	24		
Brunner et al. (Farm Comparison)	1999, 0-20cm	84	14		
KABO Bern (Monitoring)	1999-2008, 0-20cm	2	14		
Field Trial DOK, Therwil	2000, 0-20cm	24	24		
Field Trial Scheyern (Sehy)	2000, 0-20cm	12	24		
Field Trial Burgrain	2000, 0-20cm	24	48		
Field Trial DOK, Therwil	2001, 0-20cm	24	24		
KABO St. Gallen (Monitoring)	2001, 0-20cm	40	96		
Field Trial DOK, Therwil	2002, 0-20cm	24	24		
Field Trial Burgrain	2002, 0-20cm	24	48		
Field Trial DOK, Therwil	2003, 0-20cm	24	24		
Field Trial DOK, Therwil	2004, 0-20cm	24	24		
Field Trial Burgrain	2004, 0-20cm	12	24		
Field Trial DOK, Therwil	2005, 0-20cm	24	24		
KABO St. Gallen (Monitoring)	2006, 0-20cm	9	33		
Field Trial MASCOT	2006, 0-25cm	12	12		
KABO Aargau (Monitoring)	2006, 0-20cm	2	18		
Field Trial Burgrain	2006, 0-20cm	12	24		



# How Carbon Stocks are Calculated



*carbon stock(t/ha) =*

$$10 \bullet \text{soil organic carbon}(g/kg) \bullet \text{bulk density}(t/m^3) \bullet \text{depth}(m)$$

# Objectives/Approaches

## *Two Approaches:*

### ➤ **1) Carbon Stocks:**

- *Organically farmed soils in Switzerland contain higher carbon stocks than conventionally farmed soils.*

### ➤ **2) Soil Organic Carbon:**

- *Organically farmed soils in Switzerland contain higher amounts of soil organic carbon (SOC) than conventionally farmed soils.*

## *Issues 2:*

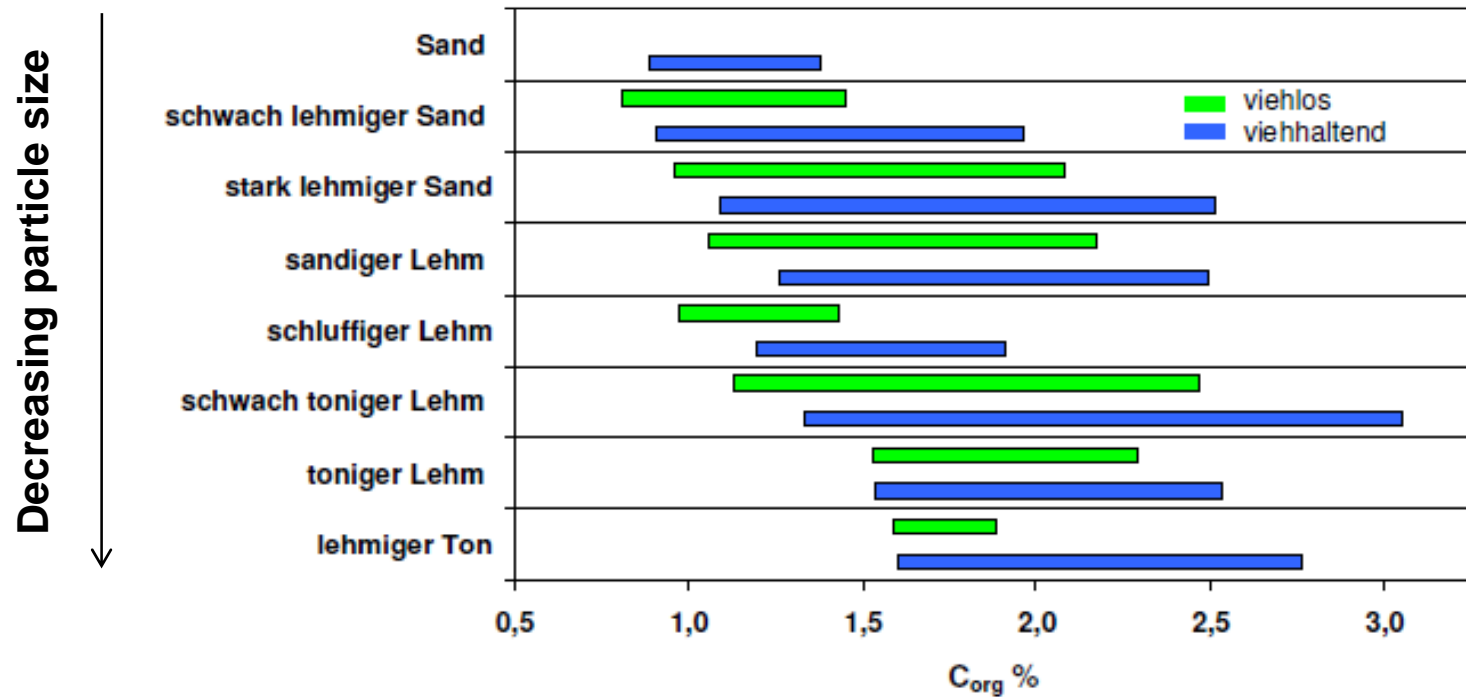
### ➤ **Basic statistical analysis shows (time line and box plots):**

- *Better and more evenly distributed data*
- **Meta-analysis (funnel plots) shows:**
  - *Heterogeneity not as large as in approach 1*
  - *Some publication bias, but not excessive*

### **3. Challenges for carbon quantification**

- 1. Site effect appears to be more influential than management practice (org. vs. conv.)  
= need for pair wise comparison**
- 2. Strong influence of livestock integration**

# Influence of soil texture and livestock integration



(n = 1276)

### **3. Challenges for quantifying sequestration performance of OA**

- 1. Site effect appears to be more influential than management practice (org. vs. conv.)  
= need for pair wise comparison**
- 2. Strong influence of livestock integration**
- 3. No target values: optimal C contents/stocks?**
- 4. Only minor changes with regard to total stocks**

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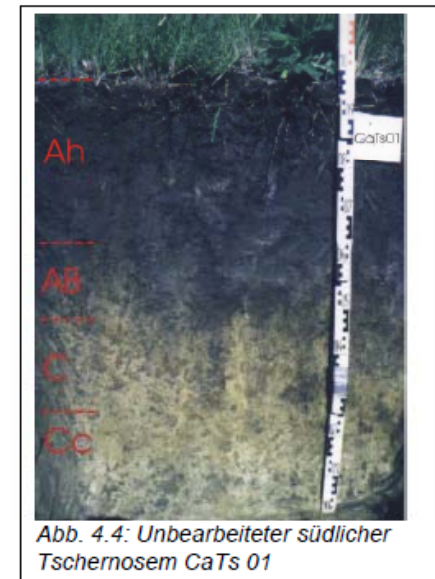
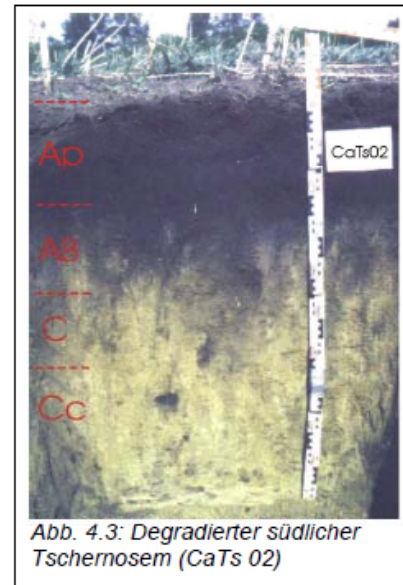
### **3. Challenges for quantifying sequestration performance of OA**

- 1. Site effect appears to be more influential than management practice (org. vs. conv.)  
= need for pair wise comparison**
- 2. Strong influence of livestock integration**
- 3. No target values: optimal C contents/stocks?**
- 4. Only minor changes with regard to total stocks**
- 5. What about the pastoralism in African countries, Mongolia: C stocks? Is this organic?**  
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- 6. ... organic farming on “organic” soils (= carbon sinks) more effective?**

# Ex: Tschernosem in Kundula (Steppe)

**Cultivation of the Steppe for arable production after second world war led to:**

- **Up to 50% C loss in the top 20 cm (= 2.5 t C/ha \* a), due to wind erosion and mineralisation**
- **Converting to grassland for erosion reduction: better „snow/water harvesting“ ability, higher water use efficiency and higher C input through plant roots used under site adapted (organic) grazing regime**



**Thank you very much for your attention!**