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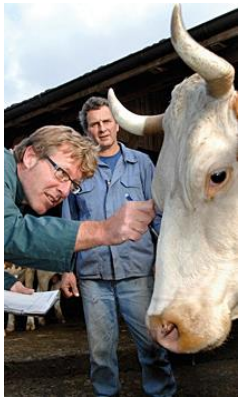

Kohlenstoffspeicherung und Treibhausgasflüsse in Böden unter biologischer und konventioneller Bewirtschaftung – Ergebnisse aus zwei globalen Meta-Analysen

A. Gattinger, C. Skinner, A. Müller, A. Fliessbach, M. Häni, P. Mäder, M. Stolze, N. Buchmann & U. Niggli

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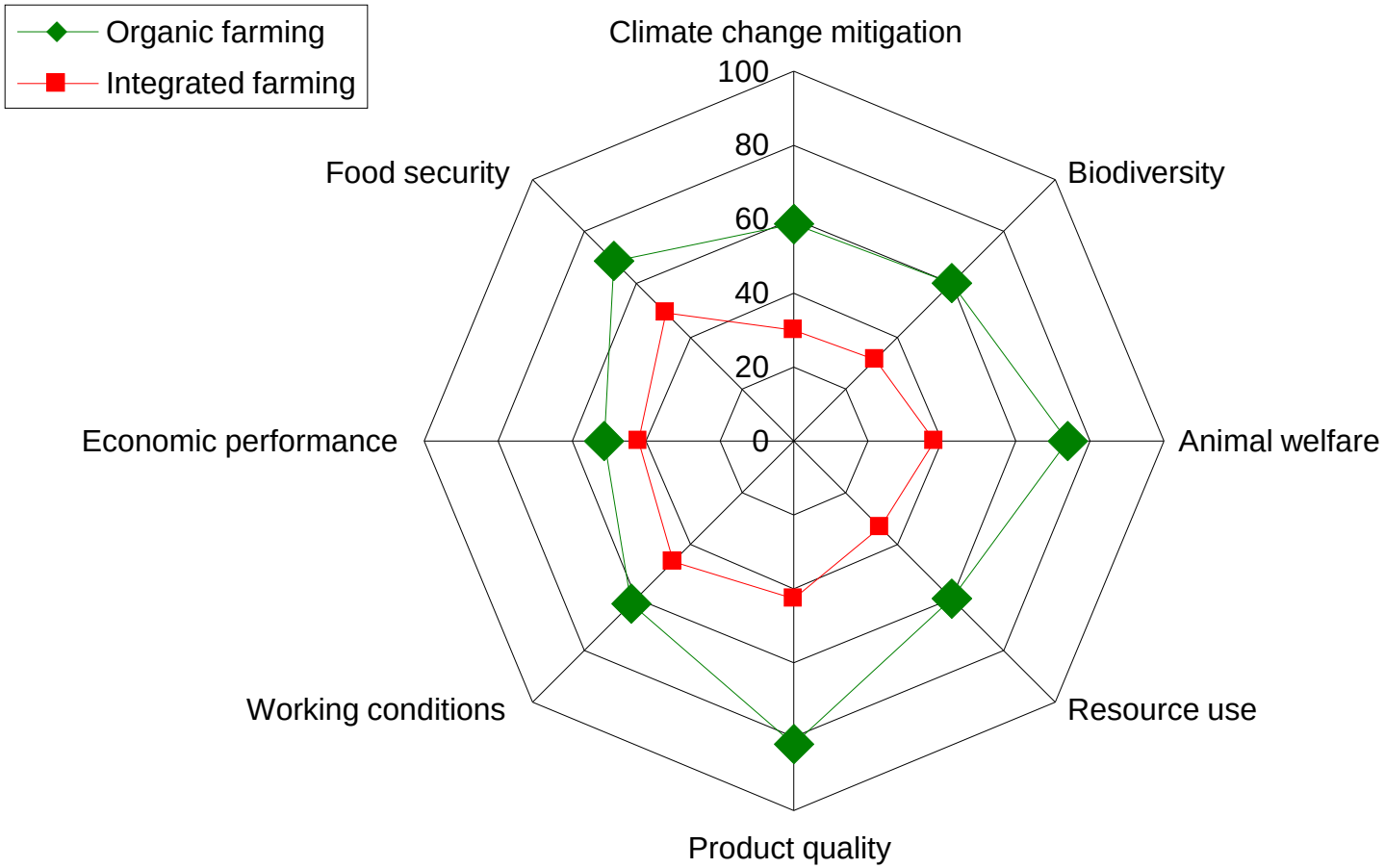
Inhalte

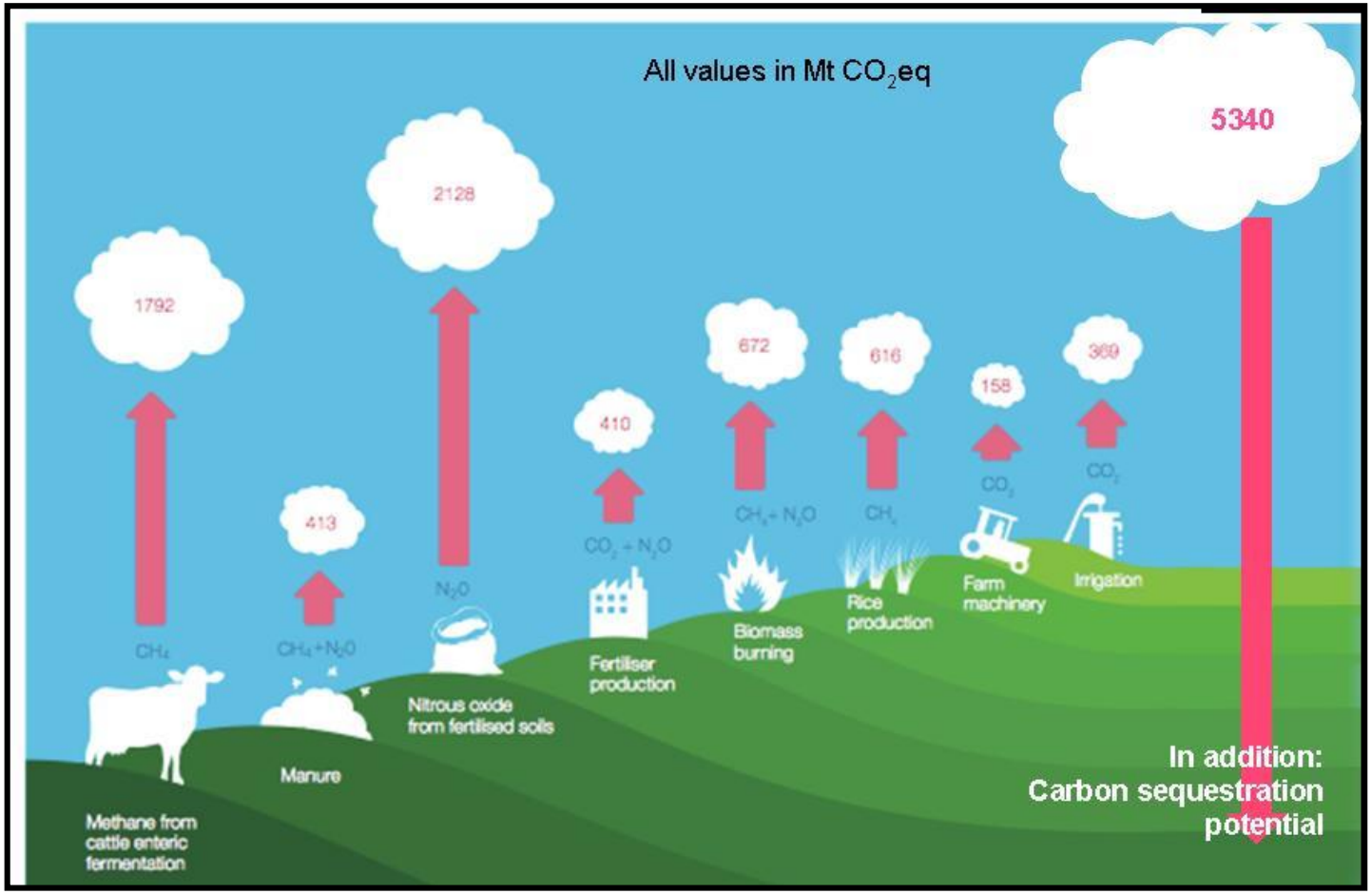
- Einleitung und Zielstellung
- Material & Methoden
- Ergebnisse
- Schlussfolgerungen

Nachhaltigkeit von Anbausystemen



Schader et al., 2012

Globale Treibhausgasemissionen der Landwirtschaft und Potenzial zur Sequestrierung von Kohlenstoff im Boden



angepasst nach Bellarby et al. 2008

Ziele

- **Meta-Analyse I:** Quantitativer Vergleich von Kohlenstoffkonzentrationen, -vorräten und C-Sequestrierungsraten in Böden unter organischer und konventioneller Bewirtschaftung

- **Meta-Analyse II:** Quantitativer Vergleich von Treibhausgasflüssen (Lachgas, Methan) aus Böden unter organischer und konventioneller Bewirtschaftung

- **Identifizierung der Einflussfaktoren** mittels Meta-Regression:
  - Standorteinflüsse (Temperatur, Niederschlag, Tongehalt)
  - Landnutzung (Acker, Grünland, etc.)
  - Managementfaktoren: Düngung, Fruchtfolge, etc.

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Methodischer Ansatz

1. Literatursuche
2. Literaturauswertung
3. Wenn positiv: Integration in Datenmatrix und Parametrisierung
4. Meta-Analysis mit *Comprehensive Meta Analysis* software und R «metafor package».

Anforderungskriterien an «gültige» System-vergleichsstudien

- Nur begutachtete Arbeiten, bei denen gemessene Daten zu Bodenkohlenstoff und THG-Flüssen erhoben wurden: a) peer-reviewed Zeitschriften b) Konferenzbeiträge/Buchkapitel/Dissertationen

- Nur solche Vergleichsstudien, bei denen Öko-Richtlinien für mindestens 3 aufeinander folgenden Jahren praktiziert wurden.

- Nur Studien basierend auf paarweisen Systemvergleichen, d.h. organische und nicht-organische (i.e. konventionell, integriert) Bewirtschaftung unter gleichen Standortbedingungen

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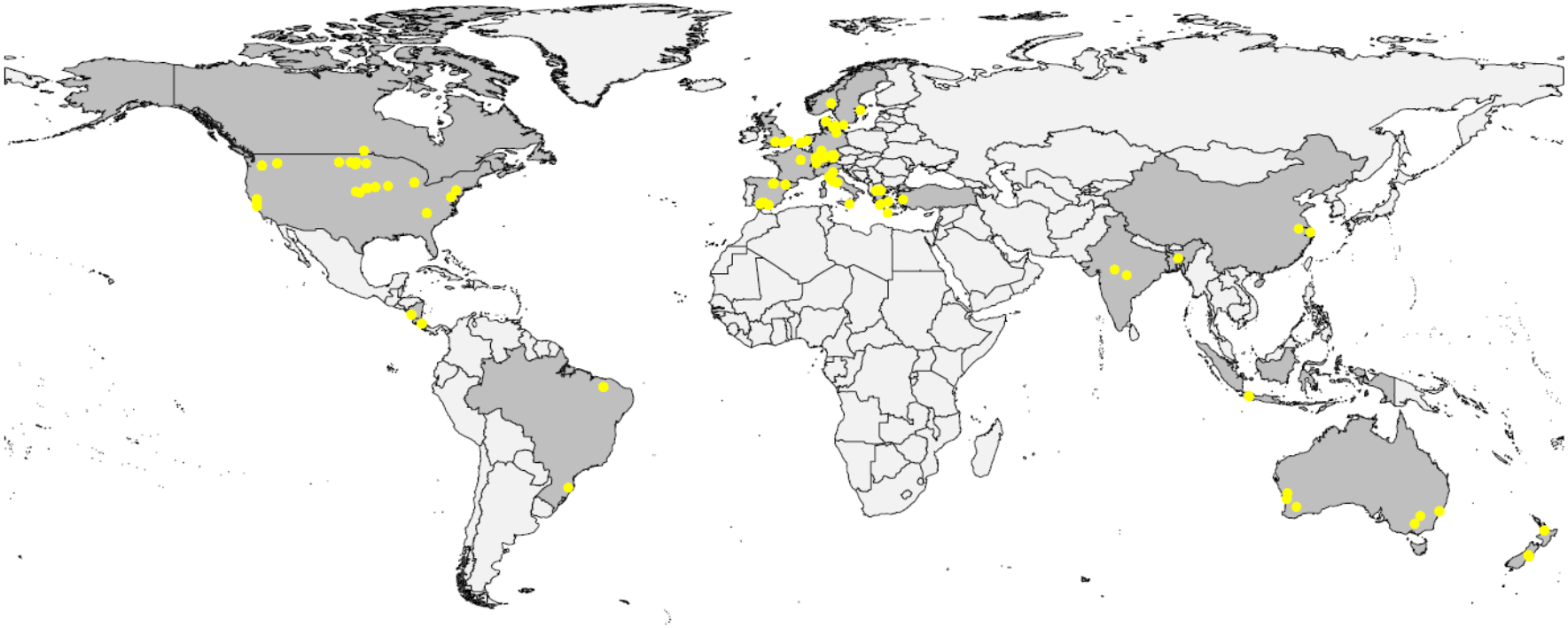
Meta-Studie I: Bodenkohlenstoff

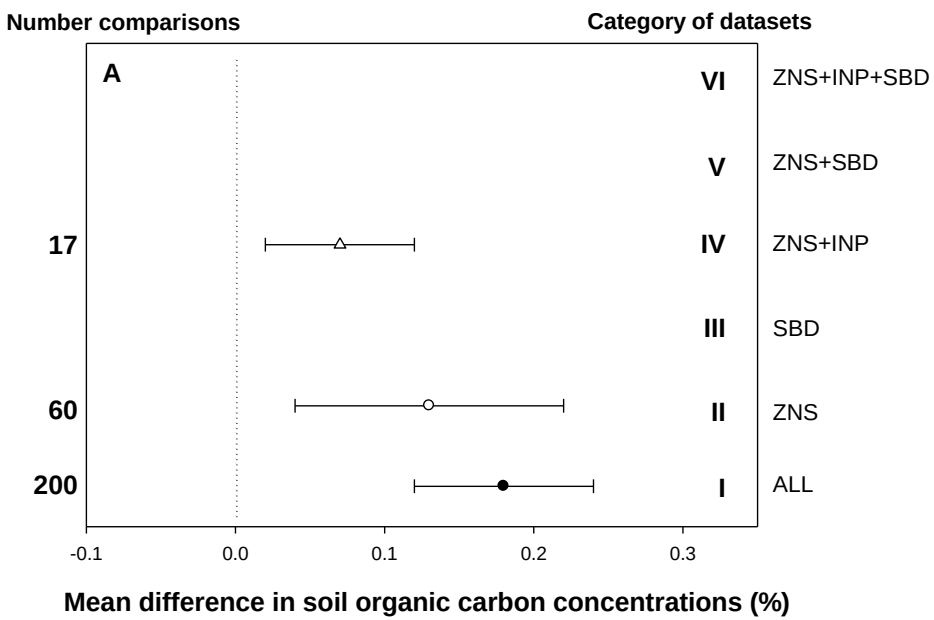
Geographische Verteilung der Systemvergleichsstudien

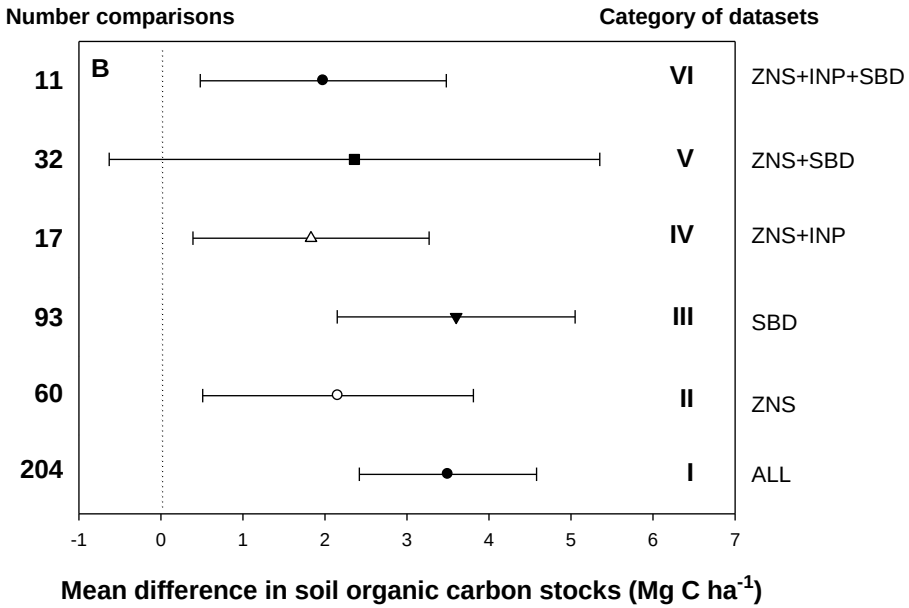


74 Vergleichsstudien weltweit mit bis zu 211 Paarvergleichen

Gattinger et al., PNAS, 2012

Mehr Kohlenstoff in biolog. bewirtschafteten Böden?

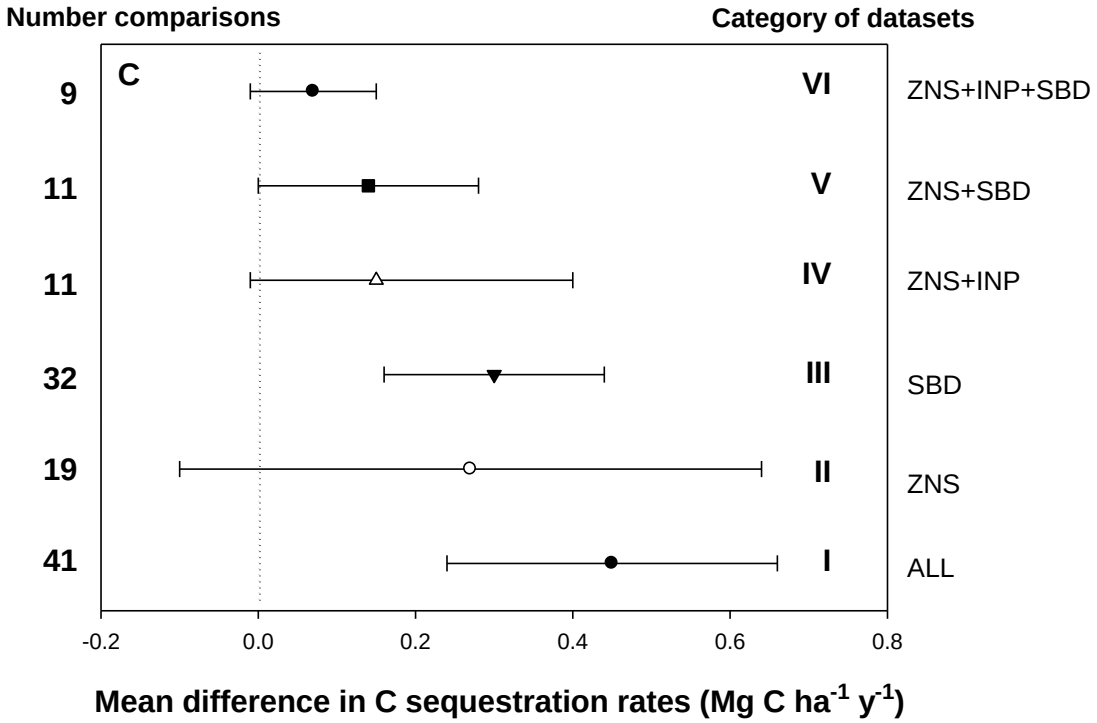




Höhere Kohlenstoffkonzentration (0,18±0,06 %-Punkte Corg) und -vorräte (3,50 ± 1,08 t Corg ha^{-1}) im Oberboden (0-20 cm) unter organischer Bewirtschaftung.

Gattinger et al., PNAS, 2012

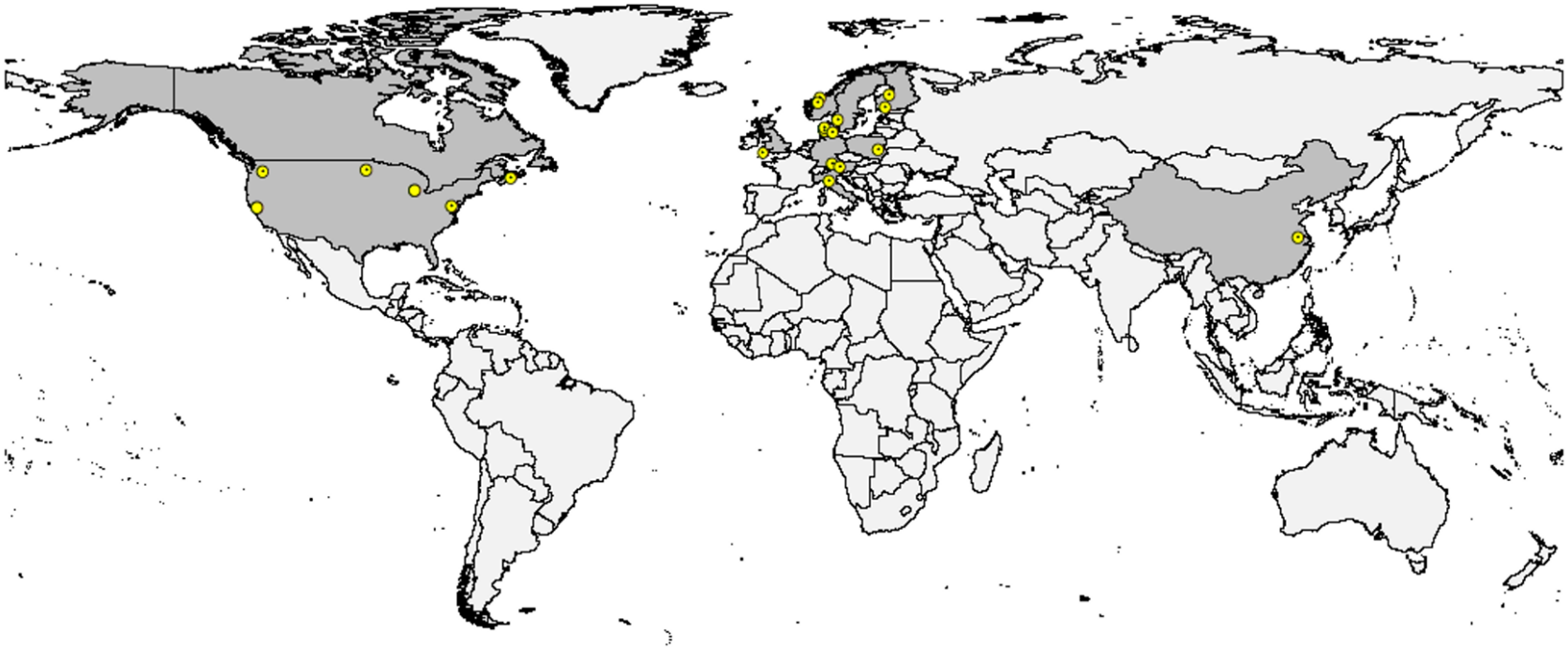
Ist Kohlenstoffspeicherung im organischen Landbau möglich?



Ja, es ist möglich. Netto-Sequestrierung von 450 kg C ha^{-1} y^{-1} für alle organ. bewirtschaftete Böden; das Potential ist niedriger unter „zero net input systems“ (≤ 1.O GVE ha^{-1}): 70 – 270 kg C ha^{-1} y^{-1}.

Gattinger et al., PNAS, 2012

Meta-Studie II: Bodenbürtige Treibhausgase (Lachgas, Methan)



18 Vergleichsstudien weltweit mit bis zu 98 Paarvergleichen

Skinner, Gattinger et al., STOTEN, submitted

Weniger N_2O aus organisch bewirtschafteten Böden?

	N_2O emissions per acreage (kg N_2O-N ha^{-1} a^{-1})					GWP [d] N_2O emissions per acreage (kg CO_2-eq. ha^{-1} a^{-1})					GWP [d] N_2O emissions per yield (kg CO_2-eq. t^{-1} DM)				
land-use	MD *	CI [b]	p	studies	comp. [c]	MD *	CI [b]	p	studies	comp. [c]	MD *	CI [b]	p	studies	comp. [c]
all (annual)[f]	-1.04	0.41	0.00	12	70	-486	191	0.00	12	70	50.5	28.9	0.00	7	25
arable	-1.01	0.42	0.00	11	67	-472	195	0.00	11	67	52.0	31.9	0.00	6	23
grassland	-2.42	5.16	0.36	2	3	-1133	2416	0.36	2	3	32.1	192.3	0.74	2	2
rice-paddies	-1.39	2.22	0.22	1	3	-650	1038	0.22	1	3	-25.7	49.1	0.31	1	3
overall[g]	-1.03	0.32	0.00	18	98	-482	150	0.00	18	98	30.7	28.9	0.04	8	30

Bezogen auf Fläche: ca. 0.5 t ha^{-1} yr^{-1} weniger CO_2 eq. in Form von Lachgas unter organischer Bewirtschaftung

Bezogen auf Ertrag: ca. 0.05 t ha^{-1} yr^{-1} mehr CO_2 eq. in Form von Lachgas unter organischer Bewirtschaftung

Skinner, Gattinger et al., STOTEN, submitted

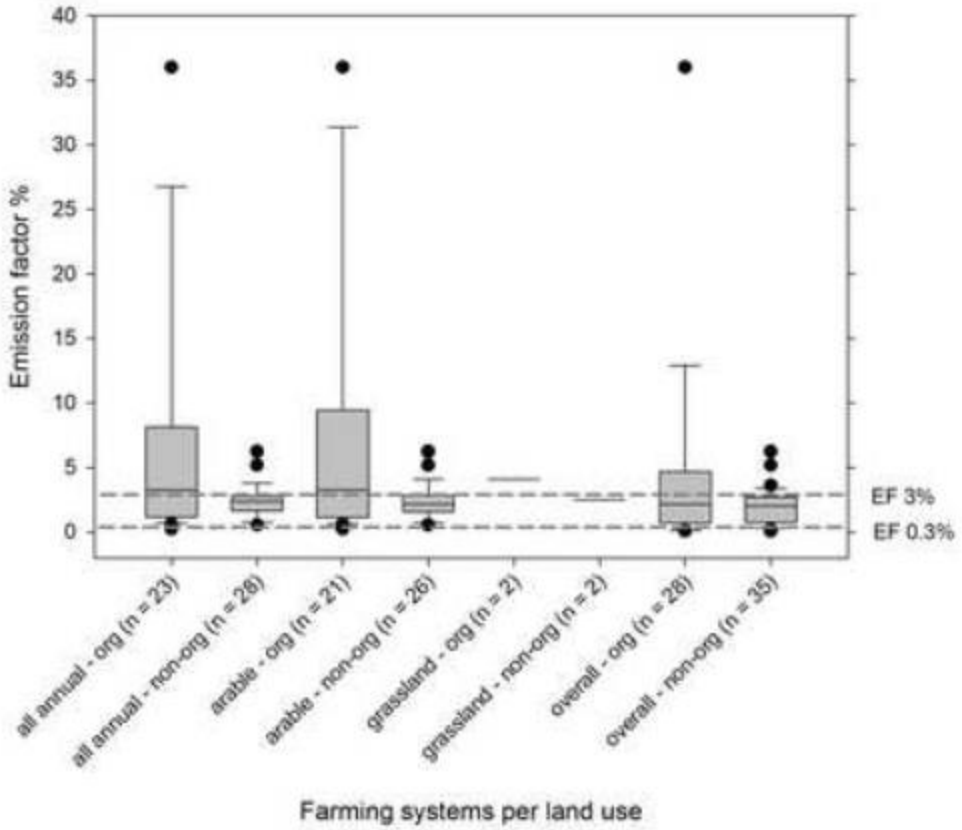
Weniger CH_4 aus organisch bewirtschafteten Böden?

	CH_4 fluxes per acreage (kg CH_4-C ha^{-1} a^{-1})					CH_4 fluxes per acreage (kg CO_2-eq. ha^{-1} a^{-1}) [f]					CH_4 fluxes per yield (kg CO_2-eq. t^{-1} DM)				
land-use	MD [a]	CI [b]	p	studies	comp. [c]	MD [a]	CI [b]	p	studies	comp. [c]	MD [a]	CI [b]	p	studies	comp. [c]
arable	-0.09	0.20	0.06	3	8	-3.1	3.3	0.06	3	8	-2.12	2.15	0.05	2	5
rice-paddies	10.55	4.77	0.00	1	3	1097	242	0.00	1	3	156.0	31.8	0.00	1	3

Nur wenige Studien, bezogen auf Fläche und Ertrag; erhöhte Methanoxidation unter organisch bew. Ackerböden, jedoch erhöhte Methanemission aus organ. bew. Reisfeldern.

Skinner, Gattinger et al., STOTEN, submitted

Vergleich der N_2O-Emissionsfaktoren



Grosse Unsicherheiten bei N_2O Emissionsfaktoren (N-Input/N_2O-N) für organische Bewirtschaftungssysteme; Notwendigkeit für mehrjährige Messungen.

Schlussfolgerungen

- Organisch bewirtschaftete Böden zeigen höhere Kohlenstoffgehalte und –vorräte, als auch eine signifikante Rückbindung von CO_2 aus der Atmosphäre. Einflussfaktoren (Meta-Regression): tendenziell Intensität der organischen Düngung und Anbau von Futterleguminosen

- Organisch bewirtschaftete Böden emittieren weniger Lachgas (N_2O) und oxidieren mehr Methan (CH_4) bezogen auf Fläche; bezogen auf Ertrag umgekehrtes Bild bei Lachgas. (Meta-Regression): Lachgas-Emissionen aus konventionell bew. Böden werden hauptsächlich durch Total N Inputs beeinflusst, während es bei organ. Böden hauptsächlich Boden-N und Boden-C Gehalte sind.

- Grosse Schwankungsbreite der N_2O-Emissionsfaktoren in organ. bew. Böden; mehrjährige Freilandmessungen zum besseren Verständnis der Einflussfaktoren notwendig.

LETTER

Organic farming gives no climate change benefit through soil carbon sequestration

Agricultural management strongly affects soil organic carbon (C), as shown by numerous long-term experiments (1). Practices known to increase soil C include adding organic manures and including grassland in crop rotations. Their effect on C is related to the net primary productivity of the agroecosystem and the fraction of organic matter remaining in the field or returned as residues.

According to Gattinger et al. in a recent issue of PNAS (2), organic farming (OF) promotes soil C increase relative to conventional farming (CF). They evaluated datasets from 74 studies and found that soils under OF had significantly higher C stocks, concentrations, and rates of C increase than those under CF and attributed these differences to the intrinsically higher C inputs in OF. In their analysis, OF received, on average, much higher external (manure, slurry, compost) C inputs (1.20 Mg C ha^{-1} y^{-1}) than CF (0.29 Mg C ha^{-1} y^{-1}). Higher soil C concentrations in OF have been attributed previously to high and often disproportionate external inputs (3); therefore, the authors also analyzed a subset of data comprising only organic trials with productivity that would support an external C input equivalent to a maximum stocking density of 1 European livestock unit (ELU) per hectare. They state that even within this reduced dataset, OF outperforms CF in terms of soil C.

Here, we argue that their interpretation is biased. In the study by Gattinger, 92% of the organic systems received external C inputs compared with only 27% of the conventional (2). The average external C input to OF was 4.14 times that of CF for the full dataset and yet still 2.12 times higher for systems supporting ≤1 ELU ha^{-1} (average annual external C input to: OF, 0.60 Mg C ha^{-1}; CF, 0.28 Mg C ha^{-1}). This bias mainly lies in a nonrepresentative selection of CF. Gattinger et al. compared systems with high stocking densities and C inputs to systems with low stocking densities and C return, which they called "organic" vs. "nonorganic" but which actually represent mixed farming vs. almost stockless systems, respectively. However, CF is not typically characterized by low stocking but by greater separation of arable and livestock systems.

In addition to this unbalanced comparison, Gattinger et al. ignore important aspects of the assessment of climate change mitigation through soil C sequestration (2). First, in most situations, manure would be applied somewhere anyhow, unless used for other purposes. Hence, an increase in soil C in one field (whether in an OF or CF system) is not a net transfer of C from atmosphere to land but a movement of C from one site to another (4). Second, OF generally gives lower crop yields than CF (5), so any expansion of OF would imply either decreased global food production or additional conversion of land with a high soil C content to cropland, leading to additional C emissions. Thus, the interpretation of Gattinger et al. that practices central to OF can mitigate climate change through C sequestration in soils is misleading.

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Author contributions: J.L. analyzed data; and J.L., D.A.A., C.C., J.F., T.K., and D.S.P. wrote the paper.

The authors declare no conflict of interest.

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LETTER

Reply to Leifeld et al.: Enhanced top soil carbon stocks under organic farming is not equated with climate change mitigation

In their letter, Leifeld et al. (1) argue that our metaanalysis to identify differences in soil organic carbon (SOC) between organic (OF) and nonorganic farming [conventional farming (CF)] (2) selected CF systems that were nonrepresentative. This was not the case. We included data from all available pairwise field comparisons between OF and CF identified in the literature. The observed difference in external carbon (C) inputs between OF and CF did not result from a bias in the selection of studies/treatments but was attributable to the fact that the field comparisons we analyzed (2) were not from fertilization experiments but from pairwise farming system comparisons where the design and the underlying treatments reflected the current farming practices in the region in which the studies were conducted at the time the experiments were initiated.

In addition, it is important to not only address external but total C inputs, i.e., organic fertilizers and plant residues. We found indications that differences in external C inputs and crop rotations were important, and we noted this. For six studies, which reported total C input data, the mean total annual C input was 4.23 and 4.86 Mg C ha^{-1} for CF and OF systems, respectively (2). The more pronounced separation of livestock and arable production in CF was also seen in the difference in crop rotation between OF and CF (2), with more forage legumes in OF, a typical feature for crop rotations of mid-European agricultural systems until the 1970s.

Furthermore, we do not believe that, universally, farmyard manure is used efficiently in CF. Because of a tendency to separate arable and livestock systems in CF in developed countries, huge amounts of manure in livestock-dense areas leads to the well-known problems of over-fertilization (3) and suboptimal C sequestration. Although the maximum C sequestration rates may be reached earlier in the fields with high external C input, fields without external C input via farmyard manure are depleted in SOC. The fact that one-third of arable soils were eroded within 40 y worldwide under intensive CF (4) underlines the need for careful SOC management via manure and crop residues.

Regarding the second part of the comment from Leifeld et al. (1), we were careful to emphasize that we do not equate SOC accumulation with mitigation. We stated, "Further, the estimation of carbon sequestration alone does not equate to climate change mitigation…", giving a range of reasons.

Finally, yields in OF tend to be lower, but this is not the case for all crops and all climate zones (5). To fully account for the impact of any differences in yield between OF and CF on greenhouse gas emissions, lifecycle emissions from all activities, including indirect land use change, would be required. That was not our aim, as is clear even from the title of the paper. Our findings are simple and clear: SOC stocks are enhanced under OF. Other impacts require further analysis.

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Author contributions: A.G., A.M., M.H., C.S., A.F., N.B., P.M., M.S., P.S., N.E.-H.S., and U.N. wrote the paper.

The authors declare no conflict of interest.

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http://www.pnas.org/content/early/2013/02/20/1221886110.citation

Danksagung

Diese Arbeiten sind Bestandteil des CaLaS-Projekts, finanziert von der Stiftung Mercator Schweiz.
Wir danken den KollegInnen weltweit, deren unermüdliche Arbeit diesen Datensatz ermöglicht hat.