



Kohlenstoff-Opportunitätskosten und deren Bedeutung für die Klimabewertung von Agrarsystemen

Tagung des Verbandes der Landwirtschaftskammern e. V. (VLK) und des Bundesarbeitskreises Düngung (BAD)

Peter Breunig

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Hintergrund

*Applied Sciences
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„Wir zeigen, dass auch wenn die Nutzung fossiler Energiequellen sofort beendet werden würde, aktuelle Trends im Agrar- und Ernährungssystem eine Erreichung des 1,5°C-Ziels verhindern und des 2°C-Ziels in Gefahr bringen würden.“

CLIMATE CHANGE

Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets

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The Paris Agreement's goal of limiting the increase in global temperature to 1.5° or 2°C above preindustrial levels requires rapid reductions in greenhouse gas emissions. Although reducing emissions from fossil fuels is essential for meeting this goal, other sources of emissions may also preclude its attainment. We show that even if fossil fuel emissions were immediately halted, current trends in global food systems would prevent the achievement of the 1.5°C target and, by the end of the century, threaten the achievement of the 2°C target. Meeting the 1.5°C target requires rapid and ambitious changes to food systems as well as to all nonfood sectors. The 2°C target could be achieved with less-ambitious changes to food systems, but only if fossil fuel and other nonfood emissions are eliminated soon.

The goal of the Paris Agreement is to limit average global temperature increases above preindustrial levels to "well below 2°C" and to pursue efforts to "limit increase to 1.5°C". Achieving either goal requires large and rapid reductions in greenhouse gas (GHG) emissions (1). To date, most efforts have focused on reducing GHG emissions from fossil fuel combustion in electricity production, transportation, and industry. Renewable energy sources, electric vehicles, improved efficiency, and other innovations and behavioral changes could eliminate most of these emissions, and carbon capture and sequestration could reduce atmospheric levels of previously emitted carbon. However, eliminating all emissions from these sectors may not be sufficient to meet the 1.5° and 2°C temperature targets. The global food system is also a major source of GHG emissions, emitting ~30% of the global total (2, 3). Nevertheless, reducing food-related emissions has received less attention, perhaps because these emissions might seem to be an unavoidable environmental cost of feeding humanity.

The global food system generates GHG emissions from multiple sources. Major sources include land clearing and deforestation, which release carbon dioxide (CO₂) and nitrous oxide (N₂O); production and use of fertilizers and other agrochemicals, which emit CO₂, N₂O, and methane (CH₄); enteric fermentation during the production of ruminants (cows, sheep, and

goats), which emits CH₄; production of rice in paddies, which emits CH₄; livestock manure, which emits N₂O and CH₄; and combustion of fossil fuels in food production and supply chains, which emits CO₂. In total, global food system emissions averaged ~16 billion tonnes (Gt) CO₂ equivalents year⁻¹ from 2012 to 2017 (4).

Here, we forecast GHG emissions from the global food system and assess whether they are compatible with the 1.5° and 2°C targets. We forecast emissions as a function of per capita diets (what is eaten and how much), the GHG intensity of various types of foods (emissions per unit of food produced, as estimated through life cycle assessment), and global population size. We assume that food systems continue to transition along trajectories of the past 50 years, which we refer to as business-as-usual (5, 6). This business-as-usual forecast makes straightforward assumptions: (i) per capita dietary composition and caloric consumption continue to change as countries become more affluent (5); (ii) crop yields, which influence how much land is converted to cropland, increase along recent trajectories (5); (iii) global population increases along the United Nations's medium-fertility pathway (7); and (iv) the GHG intensity of foods (8) and the rates of food loss and waste (9) remain constant through time.

GHG emissions from the global food system largely occur from food production and from land being cleared for food production. Emissions from food production are calculated by pairing life cycle assessment estimates of the GHG emissions per unit of each type of food (8) with their forecasted total global demand, and these estimates include emissions from activities such as production of agricultural inputs, fertilizer application, and animal husbandry. Our estimates of emissions from supply chains do not include emissions from transportation, processing, packaging, retail, and preparation, which in total account for a

minor fraction (~1%) of total food system emissions (10). Emissions from clearing land for food production are estimated by projecting crop yields, combining these with dietary projections to calculate annual rates of agricultural land-cover change with Intergovernmental Panel on Climate Change (IPCC) Tier 1 estimates of GHG emissions from land clearing or carbon storage in biomass and soil after land abandonment (11, 12).

We next determine the maximum allowable cumulative GHG emissions from all human activities from 2020 onward that are compatible with having a 67 or 50% chance of meeting the 1.5° and 2°C targets, on the basis of the thresholds set in the IPCC Special Report on Global Warming of 1.5°C (13). We call these the emissions limits. To accurately incorporate CH₄ into the cumulative emissions framework, we report emissions as global warming potential (GWP*) CO₂ warming-equivalents (CO₂-we) (14). We also show results with the more commonly used GWP100 (100-year GWP) (15). To have a 67% chance of meeting the 1.5° and 2°C targets, the cumulative emissions limits are 506 and 1405 Gt CO₂-we, respectively. For a 50% chance of meeting the targets, the emissions limits are 705 and 1816 Gt CO₂-we, respectively (see supplementary materials).

Our analysis suggests that reducing GHG emissions from the global food system will likely be essential to meeting the 1.5° or 2°C target. Our estimate of cumulative business-as-usual food system emissions from 2020 to 2100 is 1356 Gt CO₂-we (Fig. 1). As such, even if all non-food system GHG emissions were immediately stopped and were net zero from 2020 to 2100, emissions from food systems alone would likely exceed the 1.5°C emissions limit between 2051 and 2063 (date range reflects uncertainties in the 1.5°C emissions limit; see supplementary materials). Further, given our estimate of food system emissions, maintaining a 67% chance of meeting the 2°C target would require keeping cumulative nonfood emissions to <60 Gt CO₂-we in total over the next 80 years. This is slightly more than 1 year of current GHG emissions from non-food system activities (4). Maintaining a 50% chance of meeting the 2°C target would allow for 465 Gt CO₂-we in total from nonfood emissions, which is 9 years of current nonfood emissions (4). These general trends hold even if emissions from fossil fuel use in the global food system were also to be immediately halted (see supplementary materials).

We next explore how global food system GHG emissions might be reduced through five strategies that target food supply and demand: (i) globally adopting a plant-rich diet (here modeled as a diet rich in plant-based foods that contains moderate amounts of dairy, eggs,

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Emissionen des Agrar- & Ernährungssystems Deutschland

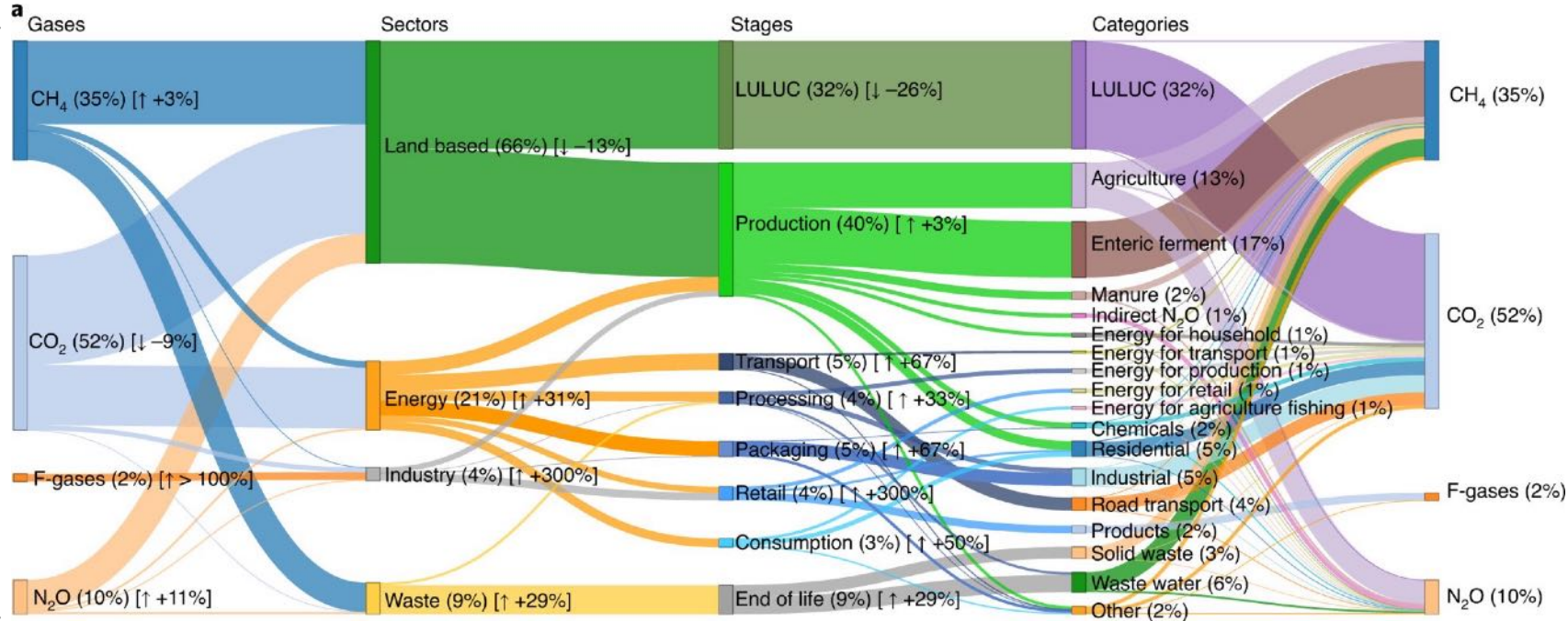
Teilbereich	In Mio. t. CO ₂ -Äqu.	% Anteil an gesamten THG-Emiss.
Emissionen aus der inländischen Landwirtschaft (Abgrenzung gemäß Klimaschutzgesetz)	68	8,6%
<i>Darunter aus tierischer Verdauung (Methan)</i>	24	3,0%
<i>Darunter landwirtschaftliche Böden (Lachgas)</i>	25	3,2%
<i>Darunter Düngewirtschaft (Methan, Lachgas)</i>	9	1,1%
<i>Darunter aus stationärer & mobiler Feuerung</i>	6	0,8%
Emissionen aus landwirtschaftlicher Bodennutzung (Acker- und Grünland, unter LULUCF bilanziert) (insbes. CO ₂)	38	4,8%
Zwischensumme: Inländische Landwirtschaft und landwirtschaftliche Bodennutzung (2019)	106	13,4%
Emissionen aus Bereitstellung von Vorleistungen der Landwirtschaft (ohne stationäre & mobile Feuerung) (Schätzung für 2007, Osterburg et al., 2013b)	22	2,8%
Emissionen aus Verarbeitung, Handel, Transport, Verpackung & Zubereitung (privat und Gastronomie) (Schätzung für 2006 (WBAE und WBW, 2016: 29)).	80-128	10,1-16,2%
Summe Agrar- und Ernährungssystem im engeren Sinn	212-262	26,7-33,0%

← 3.
← 2.
← 1.

Wichtigste Quellen in DE: Moorböden, Lachgas durch Düngung, Wiederkäuer

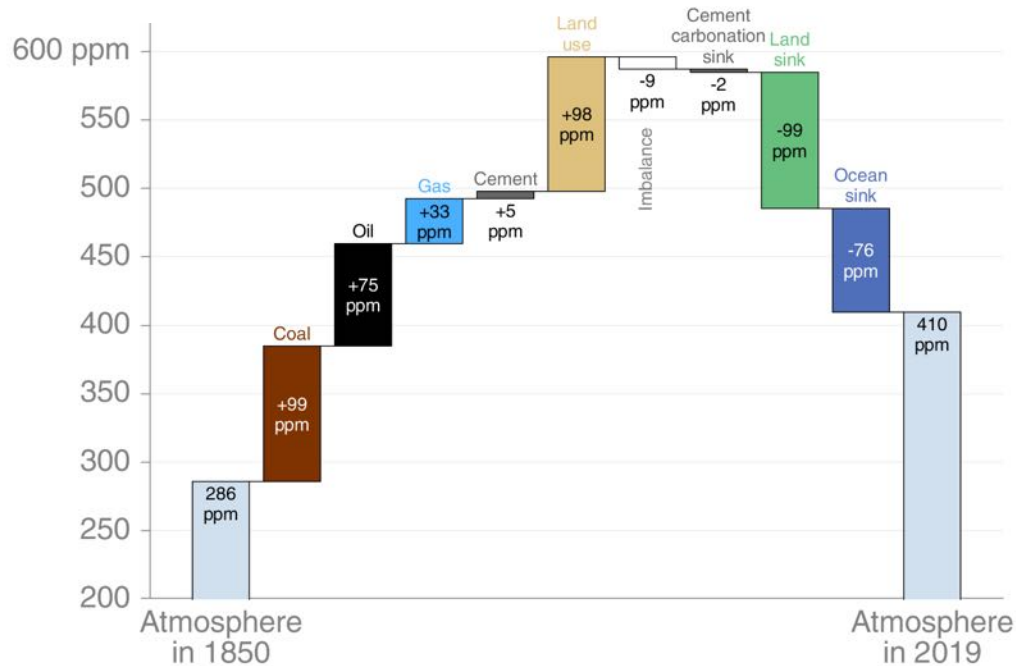
Emissionen des Agrar- & Ernährungssystems Weltweit

18 Gt CO₂e in 2015



Das globale Agrar- und Ernährungssystem ist für 1/3 aller Emissionen verantwortlich!
Wichtigste Quellen: LULUC, Wiederkäuer, Lachgas durch Düngung und Reisanbau

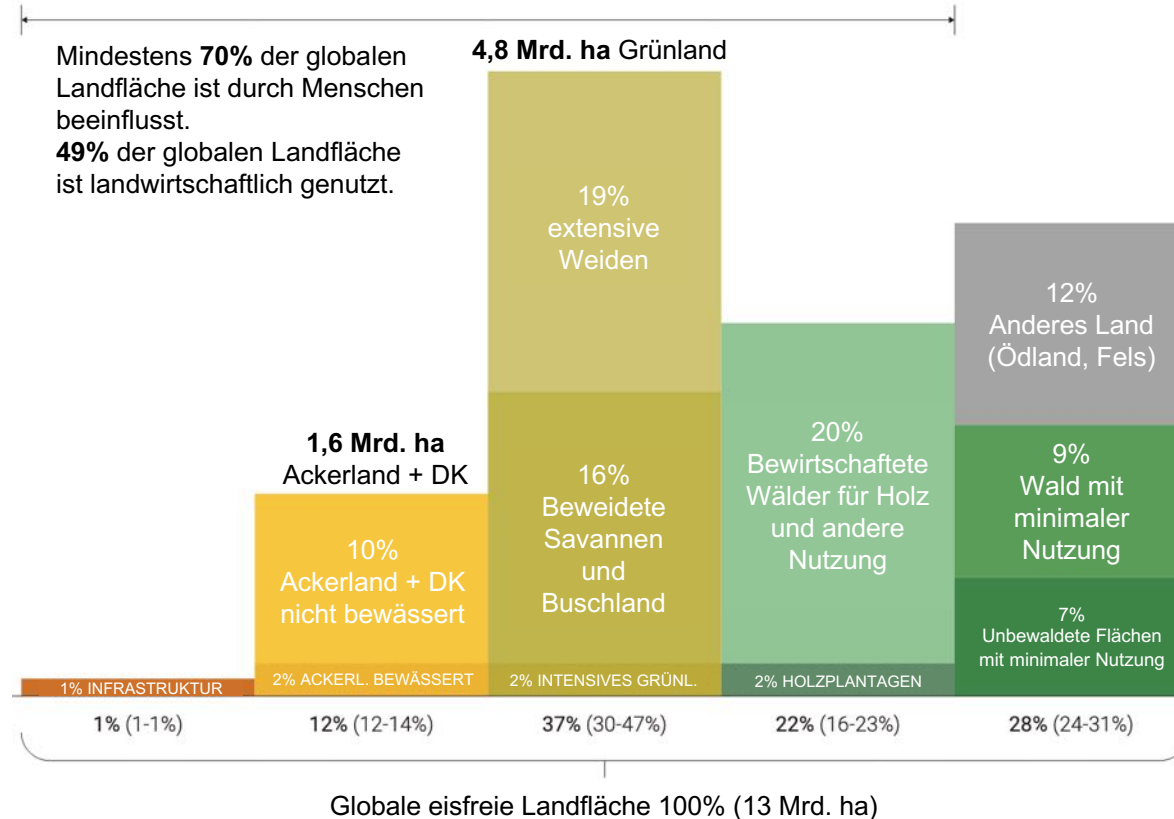
Quellen und Senken von CO₂ seit der Industrialisierung



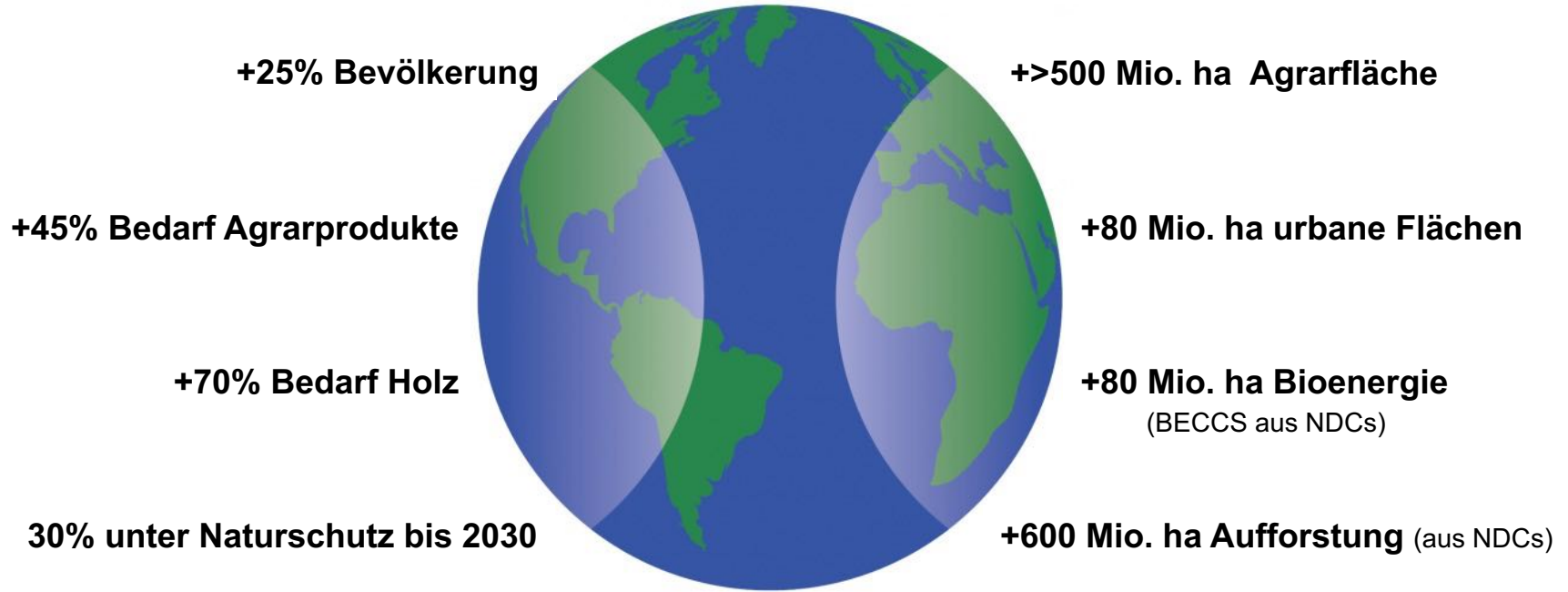
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1/3 der CO₂-Emissionen seit 1850 sind auf Landnutzungsänderung zurückzuführen!

Globale Landnutzung heute



Der globale Druck auf Land bis 2050



Kohlenstoff-Opportunitätskosten

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Ökonomie 1 t Weizen

Zahlungsströme

Saatgut

Dünger

Pflanzenschutz

Betriebsstoffe/Reparaturen

Investitionen

Lohnzahlungen

Pachtzahlungen

Vollkosten

Saatgut

Dünger

Pflanzenschutz

Betriebsstoffe/Reparaturen

Abschreibungen

Lohnzahlungen + **Lohnansatz**

Pachtzahlungen + **Pachtansatz**

Zinsansatz

Klimawirkung 1 t Weizen

Emissionsströme

Saatgut

Dünger

Pflanzenschutz

Betriebsstoffe

Maschinen

Ernterückstände

C-Veränderung Boden

Direkte oder indirekte
Landnutzungsänderung

**Produktions-
emissionen
(PEM)**

Klimakosten

Saatgut

Dünger

Pflanzenschutz

Betriebsstoffe

Maschinen

Ernterückstände

C-Veränderung Boden

**Kohlenstoff-
Opportunitätskosten (COC)**

Ansätze zur Einbeziehung von Landnutzung in die Klimabewertung

- **Direkte Landnutzungsänderung (dLUC)**

Problem: Stichtagsregelung

- **Indirekte Landnutzungsänderung (iLUC)**

Problem: Ökonomische Modelle führen per se nicht zu effizienten Lösungen



Problem:
Speicherpotenzial länger
genutzter Flächen wird
nicht berücksichtigt

- **Kohlenstoff-Opportunitätskosten (COC)**

Kohlenstoff-Opportunitätskosten (COC)

- Bei jeder Nutzung einer Fläche entgeht C-Speicherleistung der natürlichen Vegetation
- Wird dieser entgangene Nutzen nicht berücksichtigt, kommt es zu einer aus Klimaschutzsicht ineffizienten Verwendung der knappen Fläche auf unserer Erde
- Die entgangene Speicherleistung der natürlichen Vegetation ist größer als die Produktionsemissionen eines Produkts

LETTER

Corrected: Publisher Correction

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Assessing the efficiency of changes in land use for mitigating climate change

Timothy D. Searchinger^{1,2*}, Stefan WISEMANN³, Tim Beringer⁴ & Patrice Dumas^{5,6}

Land-use changes are critical for climate policy because native vegetation and soils store abundant carbon and their losses from agricultural expansion, together with emissions from agricultural production, contribute about 20 to 25 per cent of greenhouse gas emissions^{1,2}. Most climate strategies require maintaining or increasing land-based carbon³ while meeting food demands, which are expected to grow by more than 50 per cent by 2050^{3,4}. A finite global land area implies that fulfilling these strategies requires increasing global land-use efficiency of both storing carbon and producing food. Yet measuring the efficiency of land-use changes from the perspective of greenhouse gas emissions is challenging, particularly when land outputs change, for example, from one food to another or from food to carbon storage in forests. Intuitively, if a hectare of land produces maize well and forest poorly, maize should be the more efficient use of land, and vice versa. However, quantifying this difference and the yields at which the balance changes requires a common metric that factors in different outputs, emissions from different agricultural inputs (such as fertilizer) and the different productive potentials of land due to physical factors such as rainfall or soils. Here we propose a carbon benefits index that measures how changes in the output types, output quantities and production processes of a hectare of land contribute to the global capacity to store carbon and to reduce net greenhouse gas emissions. This index does not evaluate biodiversity or other ecosystem values, which must be analysed separately. We apply the index to a range of land use and consumption choices relevant to climate policy, such as reforesting pastures, biofuel production and diet changes. We find that these choices can have much greater implications for the climate than previously understood because standard methods for evaluating the effects of land use^{1,5} on greenhouse gas emissions systematically underestimate the opportunity of land to store carbon if it is not used for agriculture.

We define a more 'carbon efficient' use of land as one that increases the capacity of global land to store carbon and reduce greenhouse gas emissions (GHGs) overall, while meeting the same global food demand. For example, producing more crops, meat or milk on one hectare of land increases this carbon efficiency by increasing the global capacity to spare forests and other habitats while producing the same quantity of food. Gains in efficiency increase capacity to generate valuable outputs but do not by themselves guarantee how the added capacity will be used—for example, for more carbon or more food—or how other people might react owing to market forces. Yet because land supply is fixed, only increasing its efficiency can allow the world to meet both climate and food goals.

Governments, companies and individuals are making land-use decisions at least partially directed at reducing GHGs. Questions include whether to encourage conversion of cropland to forest or bioenergy, what targets to set for national emissions from land use and how to reduce the carbon footprint of diets or food supply chains. Yet standard evaluation methods, as discussed below and in more detail

in Supplementary Information, do not properly reflect the land's opportunity to store carbon if it is not used for agriculture, which we call its carbon storage opportunity cost. They can therefore encourage inefficient results that reduce the global capacity to store carbon.

For example, typical lifecycle assessments (LCAs), which estimate the GHG costs of a food's consumption, only estimate land-use demands in hectares without translating them into carbon costs^{6,7}. Other LCAs consider land-use carbon costs only if a food is directly produced by clearing new land⁸, or only for specific crops, meat or milk, where both that food and agricultural land overall are expanding^{9,10}. Such approaches assign no land-use carbon costs to most of the world's food production because previously converted agricultural lands have no carbon storage opportunity cost¹¹ (Supplementary Information).

Physical optimization models^{12,13} can estimate where agricultural expansion should occur to minimize carbon costs, by assuming likely crop yields of every hectare in a study area. Such models can count carbon storage opportunity costs, but they cannot account for the variability in carbon storage or crop yields in real hectares or estimate the effects of changes in their yields, output types or production methods (Supplementary Information).

Economic models provide a common approach to estimating how conversion of cropland to biofuels or forest affects carbon stored elsewhere, called 'leakage' or 'indirect land-use change' (ILUC). However, these models do not calculate the true efficiency of the changes to the hectare analysed (for example, reforesting cropland) because the models also factor in how resulting increases in food prices cause changes on other land, by other people and at others' expense. Such changes may include lower GHGs through reductions in global food consumption and, although disputed, through simulated increases in the yields (efficiencies) of other farmland¹⁴. Such estimated 'benefits', paid for by global consumers, result from the decline in food production on the hectare whose use was deliberately changed, not from gains in forest or bioenergy, and would therefore occur even if that hectare became supremely inefficient by producing nothing at all.

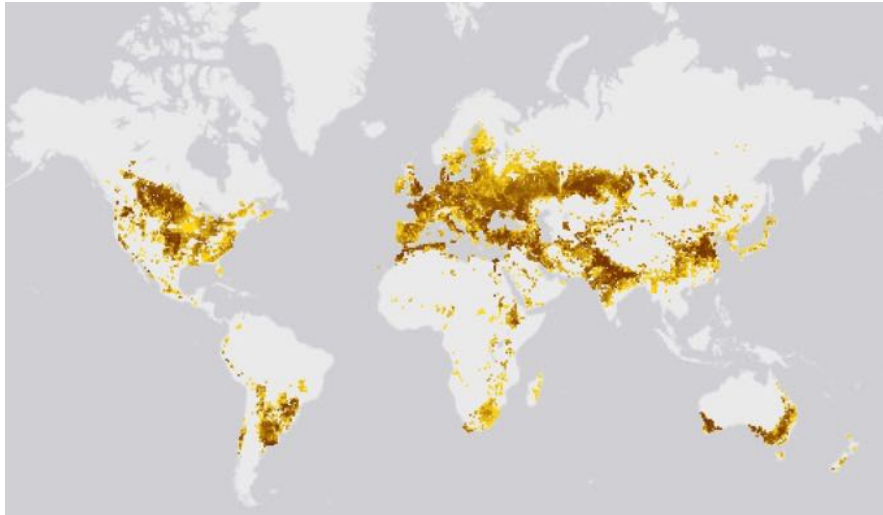
To appreciate the distinction, we imagine a possible economic analysis of a stronger climate policy banning all cars except petrol-guzzling, expensive, luxury SUVs (sport utility vehicles). The efficiency of driving would decline, increasing emissions per kilometre. However, if the cost of driving rose high enough, an economic model might estimate overall GHG savings by forcing many people to stay at home and others to switch to public transit. Even if these outcomes were real, these switches would not make SUVs more efficient than economy cars.

The actual efficiency of driving matters because governments can reduce GHGs more generally by using fuel taxes and transit subsidies to encourage less travel and higher use of mass transit while also requiring vehicles that are more fuel efficient. Similarly, if governments wished to use higher prices to reduce food consumption and spur yield gains, they could reduce GHGs more using taxes and subsidies while encouraging only efficient land-use changes (LUCs). To implement such policies, however, governments need to know which LUCs are more efficient in themselves.

Kohlenstoff-Opportunitätskosten (COC)

Wieviel Kohlenstoffbindung entspricht 1 t Weizen?

Weizenanbaufläche weltweit



- Fläche erzeugt:
750 Mio. t Weizen pro Jahr
- C-Speicherpotential der Fläche bei natürlicher Vegetation (Wald):
1,4 Mrd. t CO₂ pro Jahr
- Kohlenstoff-Opportunitätskosten (COC) bei Weizen:
1,9 t CO₂ / t Weizen

Kohlenstoff-Opportunitätskosten (COC)

Table 1 | COCs and global PEMs of major crop and livestock products

	COC ^a (kg CO ₂ per kg fresh weight)	PEMs (kg CO ₂ e per kg fresh weight)	Total (kg CO ₂ e per kg fresh weight)	Total (g CO ₂ e per kcal ^c)	Total (kg CO ₂ e per kg protein)
Maize	2.1	0.46	2.6	0.82	29
Rice (rough)	2.6	2.17	4.8	2.0	69
Wheat	1.9	0.69	2.6	0.9	23
Cassava	1.7	0.04	1.7	1.6	160
Potato	0.6	0.09	0.7	1.1	38
Soybeans	5.9	0.26	6.1	1.5	17
Pulses	10.5	0.55	11	3.1	47
Vegetable oils	9.7	1.3	11	1.2	Not applicable
Beef ^b	144	44	188	102	1,250
Cow milk	6.2	2.3	8.4	13.1	260
Pork	14	5.5	20	9.4	150
Poultry meat	11	3.7	14	8.4	110

Values are calculated using the carbon loss method and 4% time discounting.

^aIncludes peatland emissions.

^bAverage, including meat from dairy animals.

^c1 kcal = 4,184 J.

COC zukünftig auch Teil des GHG Protocols



Land Sector and Removals Guidance Part 1: Accounting and Reporting Requirements and Guidance

Supplement to the GHG Protocol Corporate Standard
and Scope 3 Standard

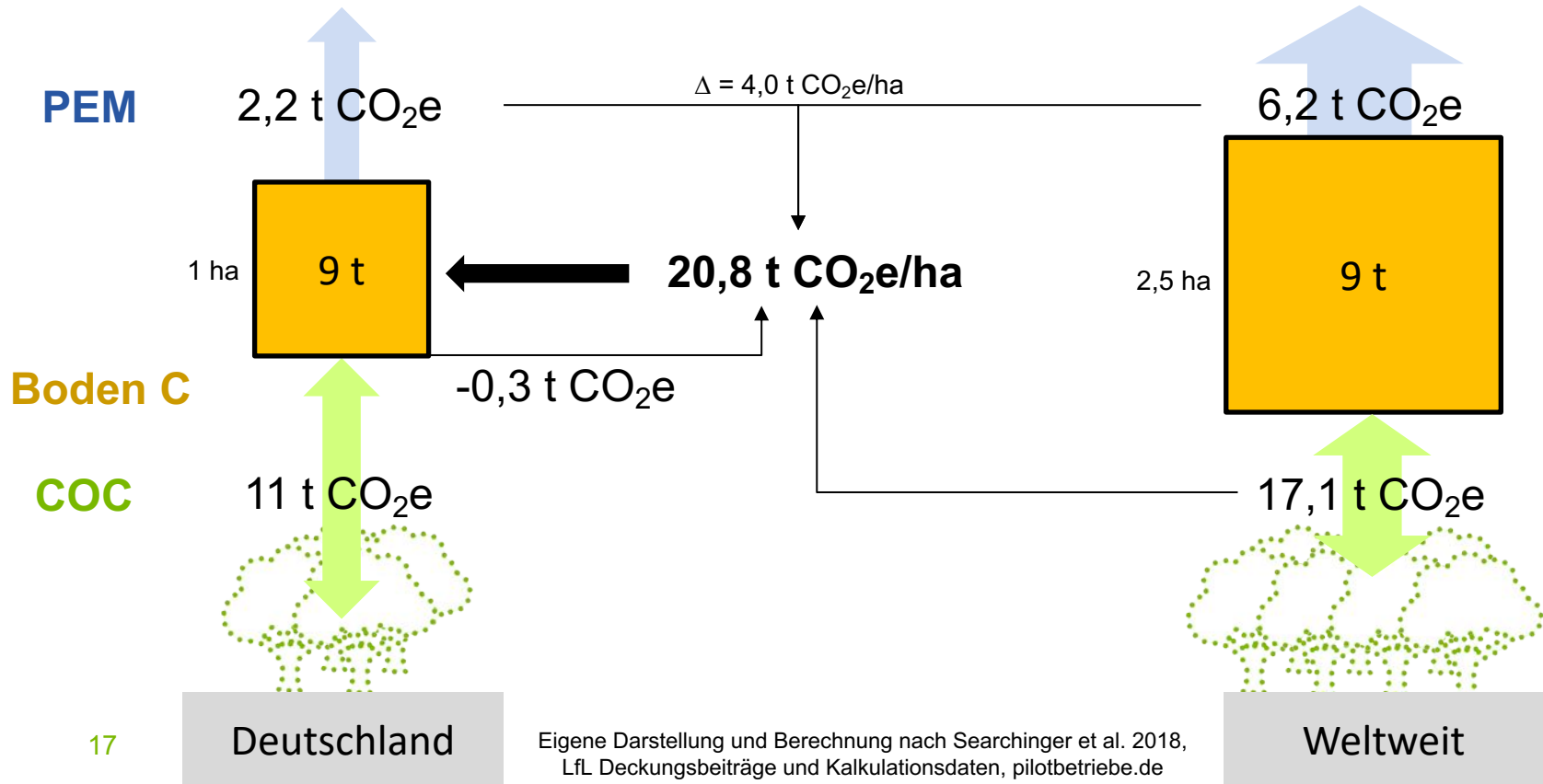
DRAFT FOR PILOT TESTING AND REVIEW
(SEPTEMBER 2022)



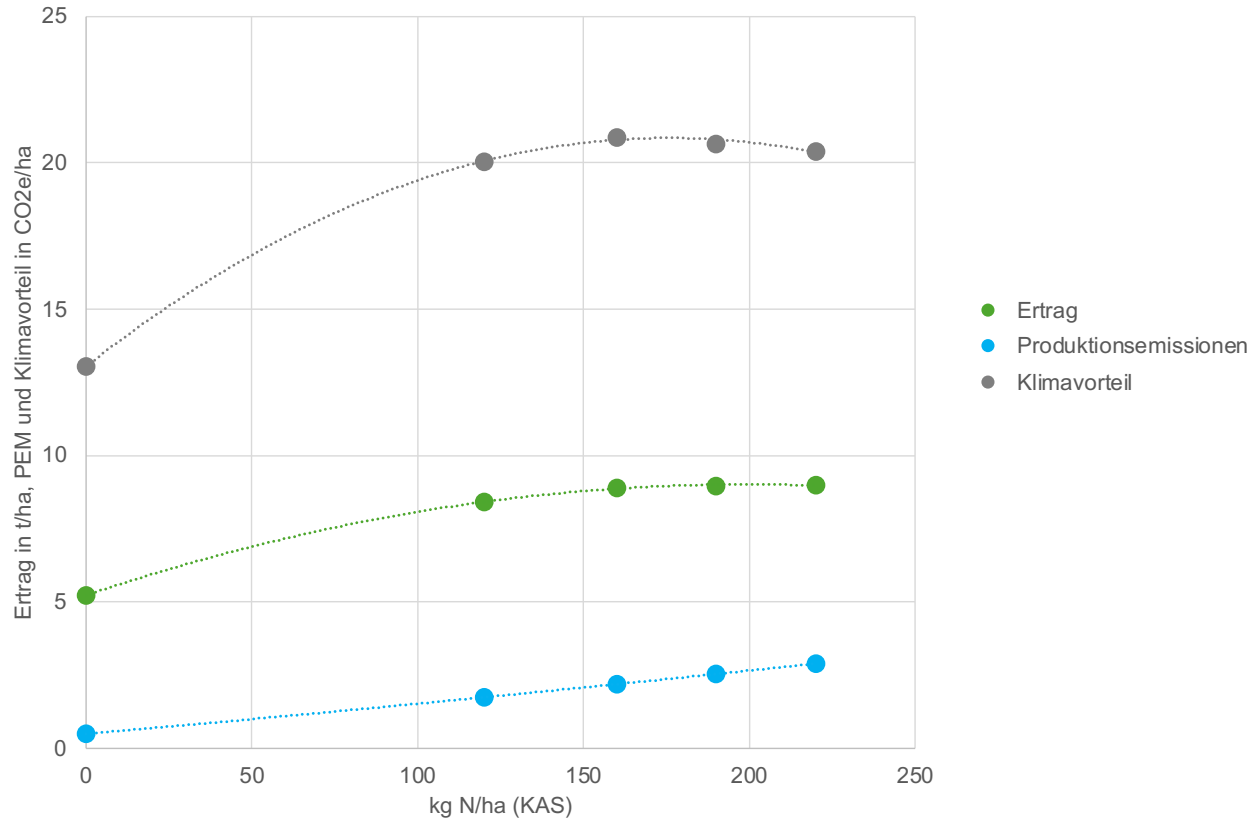
Table 7.1 Overview of metrics related to land use change

Metric	Definition	Unit of Measure	Scope(s) and relevant section
Direct land use change (dLUC) emissions	Emissions (primarily from carbon stock losses) due to recent (previous 20 years or more) land conversion directly on the area of land that a company owns/controls or on specific lands in the company's value chain	CO ₂ e	Scope 1, scope 2, and scope 3 emissions; see section 7.2
Statistical land use change (sLUC) emissions	Emissions (primarily from carbon stock losses) due to recent (previous 20 years or more) land conversion within a landscape or jurisdiction. sLUC can serve as a proxy for dLUC where specific sourcing lands are unknown or when there is no information on the previous states of the sourcing lands	CO ₂ e	
Indirect land use change (iLUC) emissions	Emissions (primarily from carbon stock losses) due to land conversion on lands not owned or controlled by the company, or in its value chain, induced by change in demand for (or supply of) products produced or sourced by the company	CO ₂ e	Scope 1, scope 2, and scope 3 land tracking; see section 7.3
Carbon opportunity costs (COC)	Emissions from total historical carbon losses from plants and soils on lands productively used (this quantity also represents the amount of carbon that could be stored if land in production were allowed to return to native vegetation)	CO ₂ e	
Land occupation	The amount of land occupied for a certain time to produce a product	hectares	

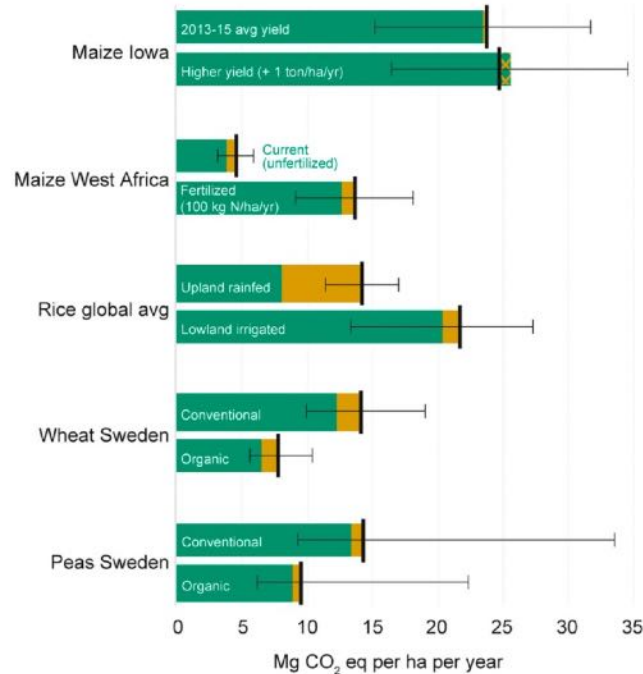
Klimavorteil von 1 ha Weizen in DE



Klimavorteil durch N-Düngung – Bsp. Weizen



Ertrag = Klimaschutz



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The greenhouse gas impacts of converting food production in England and Wales to organic methods

Laurence G. Smith, Guy J. D. Kirk, Philip J. Jones & Adrian G. Williams

Nature Communications 10, Article number: 4641 (2019) | Cite this article

59k Accesses | 35 Citations | 1362 Altmetric | Metrics

Abstract

Agriculture is a major contributor to global greenhouse gas (GHG) emissions and must feature in efforts to reduce emissions. Organic farming might contribute to this through decreased use of farm inputs and increased soil carbon sequestration, but it might also exacerbate emissions through greater food production elsewhere to make up for lower organic yields. To date there has been no rigorous assessment of this potential at national scales. Here we assess the consequences for net GHG emissions of a 100% shift to organic food production in England and Wales using life-cycle assessment. We predict major shortfalls in production of most agricultural products against a conventional baseline. Direct GHG emissions are reduced with organic farming, but when increased overseas land use to compensate for shortfalls in domestic supply are factored in, net emissions are greater. Enhanced soil carbon sequestration could offset only a small part of the higher overseas emissions.

Emissionen steigen um 21% trotz höherer C-Sequestrierung im Ökolandbau

Trends in Plant Science

Special issue: Climate change and sustainability | Forum

Genetically modified crops support climate change mitigation

Emma Kovak, Dan Blaustein-Reif, and Metin Qaim

Genetically modified (GM) crops can help reduce agricultural greenhouse gas (GHG) emissions. In addition to possible decreases in production emissions, GM yield gains also mitigate land-use change and related emissions. Wider adoption of already-existing GM crops in Europe could result in a reduction equivalent to 7.5% of the total agricultural GHG emissions of Europe.

The public debate about GM crops and new genomic breeding technologies remains contentious, especially in Europe. Critics focus primarily on hypothetical risks, while ignoring actual and potential benefits. Various reviews of the scientific literature show that the adoption of GM crops leads to economic, environmental, and health benefits through higher crop yields, higher farm profits, and, in some cases, lower chemical pesticide use. A few studies also show that certain GM crop applications help reduce GHG emissions and support carbon sequestration in the soil by facilitating reduced tillage farming. Here, we argue that the yield increases of GM crops can have additional positive effects on climate change mitigation that have not been previously considered and quantified. As global demand for food production continues to grow, crop yield increases can reduce the need to add new land into production, thus preventing additional CO₂ emissions from land-use change.

Widespread GM crop adoption in the EU with increased yields would lead to higher EU exports, lower imports, and, thus, decreases in production and land-use change emissions. For instance, the EU currently imports over 30 million tons of soybean and soybean-meal annually, mostly from Brazil, Argentina, and the USA.

Currently, land-use change accounts for over 30% of agricultural GHG emissions [1].

To support our argument, we demonstrate the climate benefits that would occur through more widespread GM crop adoption in the European Union (EU). In particular, we estimate to what extent GHG emissions would be reduced if the EU level of GM variety adoption of five major crops (maize, soybean, cotton, canola, and sugarbeet) was similar to adoption levels in the USA [see [2]] for details on methods). We focus on the EU for two reasons. First, the EU has not yet widely adopted GM crops, mostly due to issues with public acceptance and related political hurdles [3]. Hence, we can compare a hypothetical scenario with GM crop adoption to the status quo, in which hardly any GM crops are grown. Second, the EU is undergoing a reassessment of its GM regulatory policies; thus, this analysis could help provide a more comprehensive picture of likely effects of policy change.

While various GM traits have been developed, the most widely adopted ones globally are insect resistance (IR) and herbicide tolerance (HT). These traits help reduce crop damage from insect pests and weeds, respectively, thus increasing effective yields. A global meta-analysis showed that the average yield advantages of GM crops are ~22%, with some differences between traits and geographical regions [4]. The average yield increases from GM crop adoption in temperate-zone industrialized countries are ~10% and 7% for IR and HT, respectively. These assumptions appear realistic for the EU if existing GM varieties were adopted.

Widespread GM crop adoption in the EU with increased yields would lead to higher EU exports, lower imports, and, thus, decreases in production and land-use change emissions. For instance, the EU currently imports over 30 million tons of soybean and soybean-meal annually, mostly from Brazil, Argentina, and the USA. Especially in the Brazilian Amazon, the expansion of the soybean area for export contributes significantly to tropical deforestation [11]. The EU also imports over 15 million tons of maize annually from Ukraine, Russia, Brazil, and a few other countries. Some of these imports could be reduced with the use of yield-increasing GM varieties in the EU, leading to lower global GHG emissions. We consider two components of GHG emissions: the carbon opportunity costs (COCs) of land use, and production emissions (PEMs). COCs represent the opportunity that a change in production, such as increased yields, in one location reduces land-use change or stores carbon elsewhere. COCs are influenced by the carbon stocks in the native vegetation and in the soil, as well as by crop yields in the different locations. Shifting production toward locations with yields above the global average (as in the EU) enables greater carbon storage on spared land elsewhere. PEMs are calculated based on fertilizer and energy input use in agricultural production. Shifting production toward places with PEMs below the global average (as in most of the EU) lowers total global PEMs. We find that growing GM crops in the EU would reduce GHG emissions by 33 million tons of CO₂ equivalents per year (MCO₂e/yr), which is equivalent to 7.5% of the total agricultural GHG emissions of the EU in 2017. The avoided emissions per hectare are higher for maize than for other crops (Figure 2A) because GM varieties with stacked IR and HT traits are widely available for maize. Maize also accounts for the largest share (80%) of the total GM-related emission reductions (Figure 2B) because maize is grown on larger areas than the other four crops. For all five crops, COCs comprise a larger proportion (~64%) of the total potential avoided GHG emissions compared with PEMs, underlining the importance of considering land-use change effects when estimating the climate benefits.

EU-Agrar-Emissionen würden durch GVO um 7,5% sinken

Klimawirkung von Zwischenfrüchten vor Mais

	EU27 Average per ha t CO ₂ e/ha
Carbon Land Benefit based on Yield Gain	1,46
Carbon Sequestration	1,43
Carbon Benefit based on Nitrogen Fertilizer Savings	1,03
Reduced N ₂ O Emissions due to less Leaching	0,10
Albedo change	0,20
Total Climate Benefit	4,23
N ₂ O Emissions	0,04
Foregone Net GHG Benefit of Wheat due to CC Seed Land Requirements	0,28
Production Emissions Catch Crop Seed	0,39
Processing, Packaging and Transport of Catch Crop Seed	0,08
Additonal Machinery Operations	0,14
Total Climate Cost	0,93
Net Climate Change Mitigation Impact of Cover Crops	3,30

Abwägung Flächennutzung

	Klimavorteil t CO ₂ e/ha & Jahr
a) GLÖZ 8 Stilllegung	2
b) Biokraftstoffe in DE (inkl. Koppelprodukte)	7
c) Biogas mit Silomais (inkl. 1/3 Wärmenutzung)	8
d) Aufforstung / Hecken	11
e) Weizen (9 t/ha)	21
f) Milch von Grünland (4.000 kg ECM/ha)	29
g) Wiedervernässung von Moorflächen	35
h) Freiflächen PV	>300*
i) Windenergie	>10.000*
j) Biogas & Biokraftstoffe aus Gülle/Reststoffen	Keine Flächenkonkurrenz
k) PV auf Dächern und Parkplätzen	
l) Humusaufbau	

*Klimavorteil sinkt wenn EE-Anteil im Strommix steigt

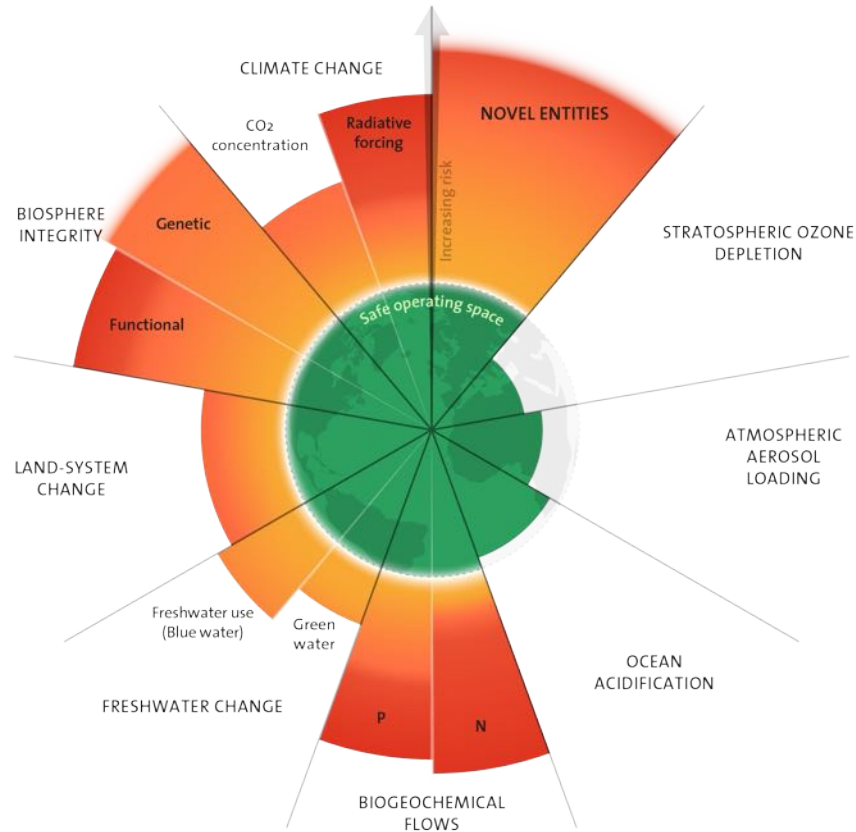
Aber...

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Aber...

1. Nachhaltigkeit ist mehr als Klimaschutz
2. Rebound-Effekte der Ertragssteigerung

Nachhaltigkeit ist mehr als Klimaschutz

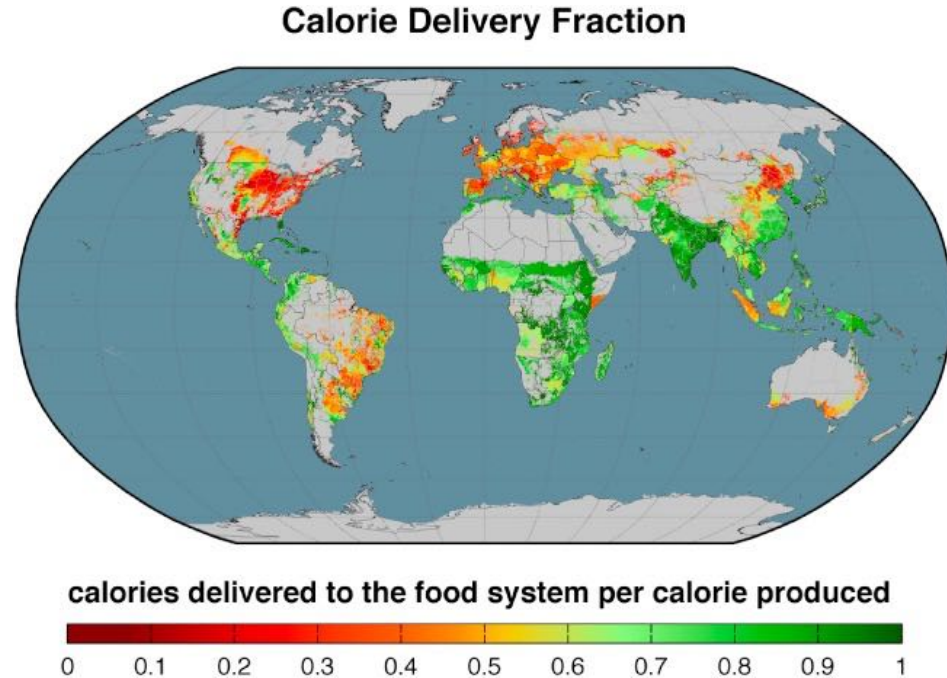
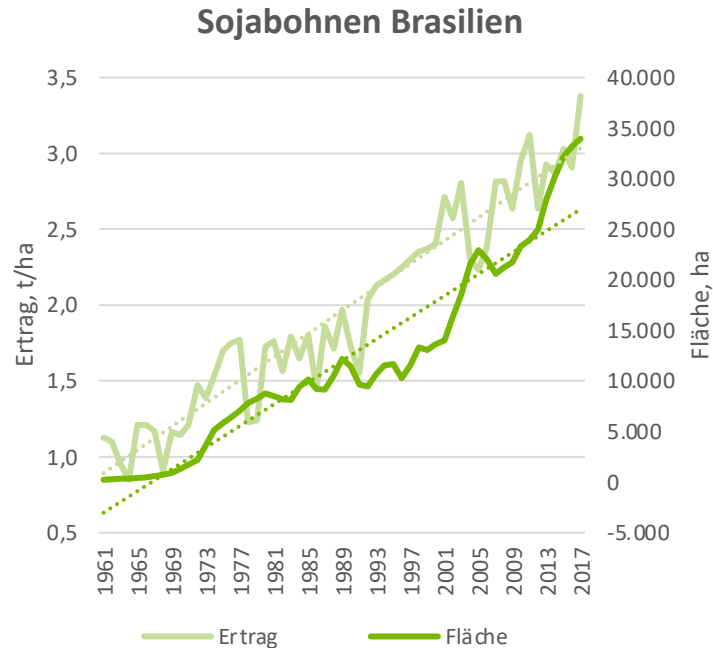


Nachhaltigkeit ist mehr als Klimaschutz

Ansatz: Minimumanforderungen erfüllen und Win-Win-Optionen bei hohen & stabilen Erträgen umsetzen

- Hohe Erträge mit mind. 20% naturnahen Flächen in der Landschaft verbinden (Tschardt et al. 2021)
- Räumliche, zeitliche und biologische Diversität von Agrarsystemen erhöhen (Rasmussen et al. 2024)
- Input-Effizienz weiter steigern, insbesondere bei N und PSM (Gu et al. 2023)
- Low-Impact-Inputs: Green Ammonia N-Dünger etc.

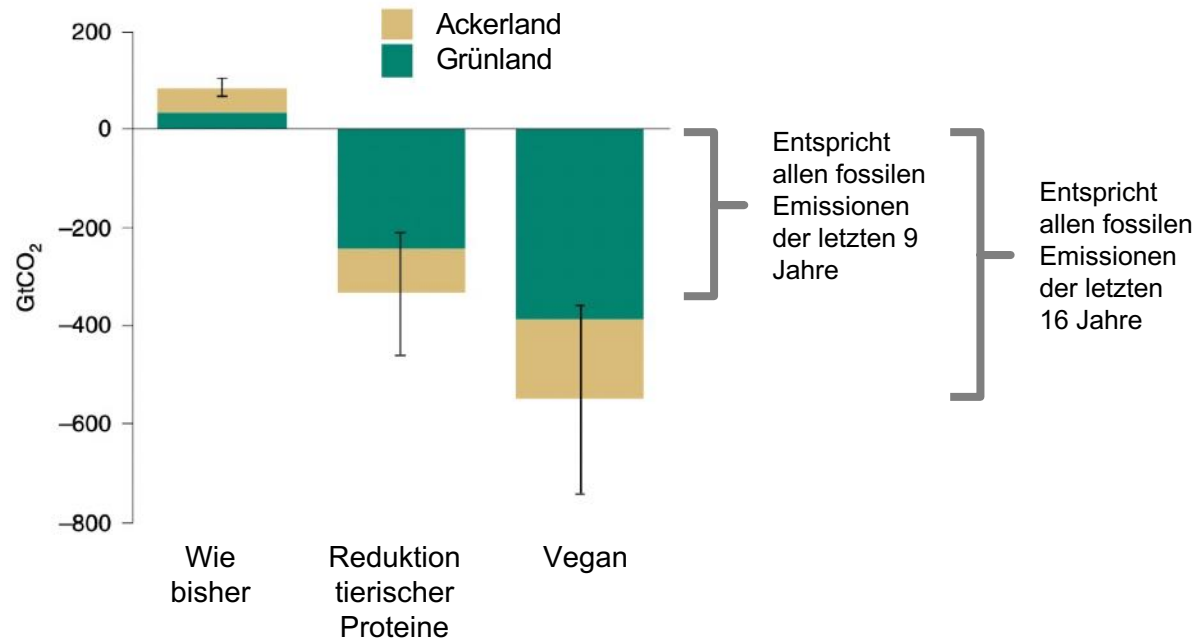
Rebound-Effekte der Ertragssteigerung



Rebound-Effekte der Ertragssteigerung

- Schutz von natürlicher Vegetation muss global an Bedeutung gewinnen
- Flächeneffiziente Erzeugung braucht **flächeneffiziente Nachfrage**:
 - Stärker pflanzenbasierte Ernährung (Hayek et al. 2021)
 - Weniger Verluste
 - Reduktion der energetischen Nutzung von Anbaubiomasse (Searchinger et al 2018)
- Forschung zur Integration von COC in Marktmodellierung

Flächeneffiziente Nachfrage durch stärker pflanzenbasierte Ernährung



Zusammenfassung

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Zusammenfassung

- Flächennutzung ist der größte Treiber der Klimawirkung des globalen Agrar- und Ernährungssystems
- Bisherige THG-Bilanzierungsansätze betrachten die Flächennutzung unzureichend – COC bieten einen universellen Ansatz
- Durch Einbeziehung von COC wird der Ertrag einer Fläche als positive Klimawirkung durch Flächeneinsparung sichtbar
- Dies ist die zweitbeste Lösung, um die knappe Fläche klimaeffizient zu nutzen (nach einem globalen CO₂-Preis)
- Die Einbeziehung von COC entbindet aber nicht von einer Abwägung zwischen anderen Nachhaltigkeitsdimensionen und Rebound-Effekte müssen betrachtet werden

Danke.