GHG-emissions measurements on cows grazing

The example of an eco-efficient low-cost milk production based on Jerseys in Northern Germany

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Introduction: Challenges of spezialized farming

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Recent intensification in European agricultural production is accompanied by serious environmental trade-offs questioning the sustainability of current specialized production systems for both all arable cash crops and animal products.

Current challenges in intensive agriculture:

a) High demand for external resources
b) Reduced biodiversity
c) High N- and P-surpluses
d) Increasing social demands with respect to animal welfare
e) Climatic impacts

Aim of the here presented project carried out on farm level:

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Can the reintroduction of a dairy herd on a former specialized all arable farm reduce theses challenges and produce milk profitably in a climatic friendly way?

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The here presented results are based on the two published papers:

Reinsch T, Loza C, Malisch CS, Vogeler I, Kluß C, **Loges R**, Taube F 2021. **Toward Specialized or Integrated Systems in Northwest Europe: On-Farm Eco-Efficiency of Dairy Farming in Germany.** Front. Sustain. Food Syst. 5, 614348. https://doi.org/10/gj68j4

Loza C, Reinsch T, **Loges R,** Taube F, Gere JI, Kluß C, Hasler M, Malisch CS 2021. **Methane Emission and Milk Production from Jersey Cows Grazing Perennial Ryegrass–White Clover and Multispecies Forage Mixtures.** *Agriculture* 11, 175. https://doi.org/10/gh4n97

Introduction: Why being interested in mixed farming?

Several authors recommend a paradigm change from highly specialized production systems back to integrated crop livestock systems (ICLS) **in order** to increase diversity of land use and resource efficiency as a strategy to enhance sustainability and to reach the environmental protection goals (Rockström et al., 2009; Ryschawy et al., 2012; Godfray and Garnett, 2014).

Many studies indicate positive environmental effects of ILCS (Ryschawy et al., 2012; Moraine et al., 2014; Peterson et al., 2020) **due to** improved C- and N-cycling among the systems and consequently a lower demand for external resources, **Thus,** lower N- and P_2O_5 surpluses can be attained

Several studies found positive effects on soil organic carbon (SOC) with increased rates of sequestration in diversified crop rotations

The latter has mainly been observed, when grass or grass-clover was included into the crop rotation (Lemaire et al., 2015; Loges et al., 2018)

Why being interested in grazing dairy cows on a mixed farm?

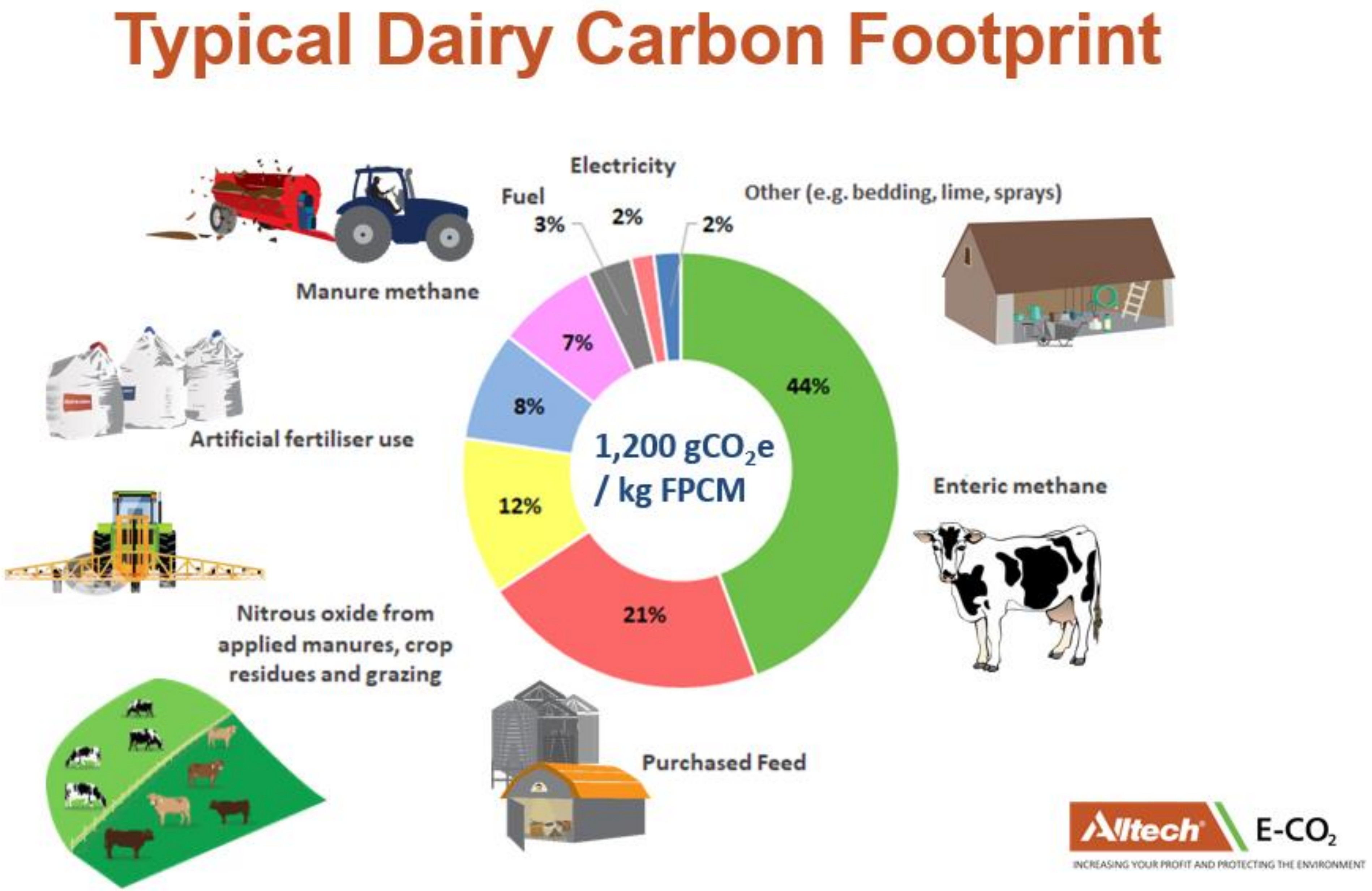
Under the temperate conditions of North-West Europe, ruminant-based integrated crop-livestock systems are considered as a strategy towards ecological intensification.

Pasture is considered a cheap and environmentally friendly forage source (Dillon et al. 2008, Rotz et al. 2009)

Cows are able to transform non edible organic matter (grass, catch crops and by-products) to high valuable protein

Customers consider grazing as essential for animal welfare and are willing to pay premium price for pasture based milk
(Zühlsdorf et al. 2014)

Greenhouse Gas –Emissions in CO_2-equivalents per kg fat and protein corrected milk (FPCM) based on an assesement of over 9000 farms in Europe (Alltech 2019)



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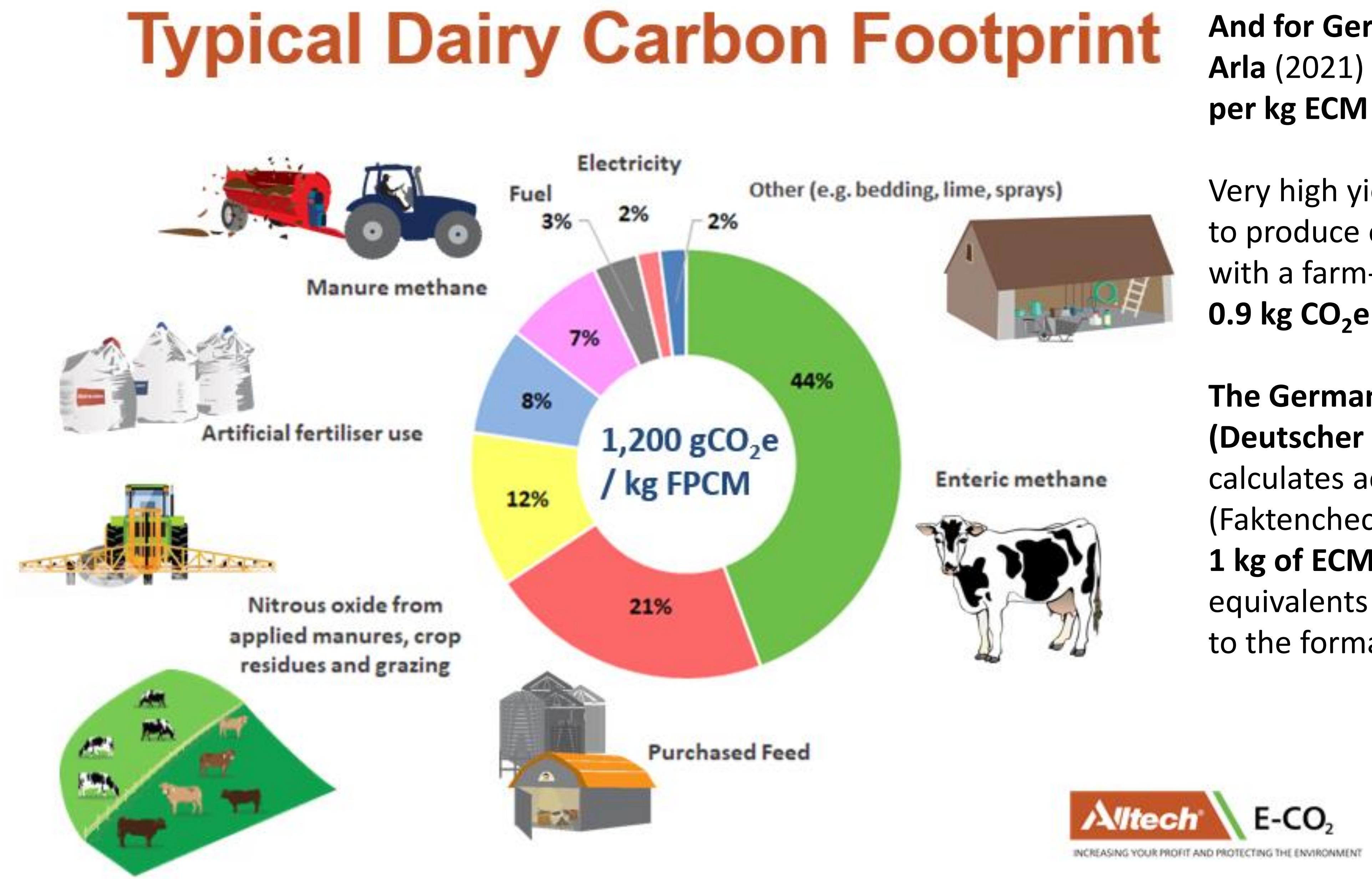

And for Germany
Arla (2021) calculates with **1.15 kg CO_2e per kg ECM**

Very high yielding Arla farmers are able to produce one kilogram of raw milk with a farm-level footprint of less than **0.9 kg CO_2e per kilogram of ECM milk**.

The German Farmers Association (Deutscher Bauernverband) (2019) calculates according to their Fact-check (Faktencheck): „The production of **1 kg of ECM-milk, around 1.1 kg of CO_2** equivalents are generated mainly due to the formation of methane

Meta study of pasture based compared to all year indoors milk production with respect to Product Carbon Footprint on the base of over 100 international published scientific papers

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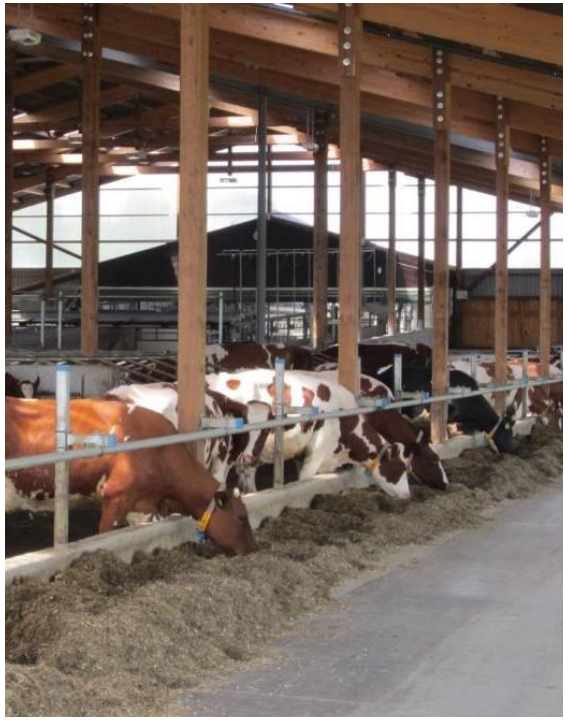
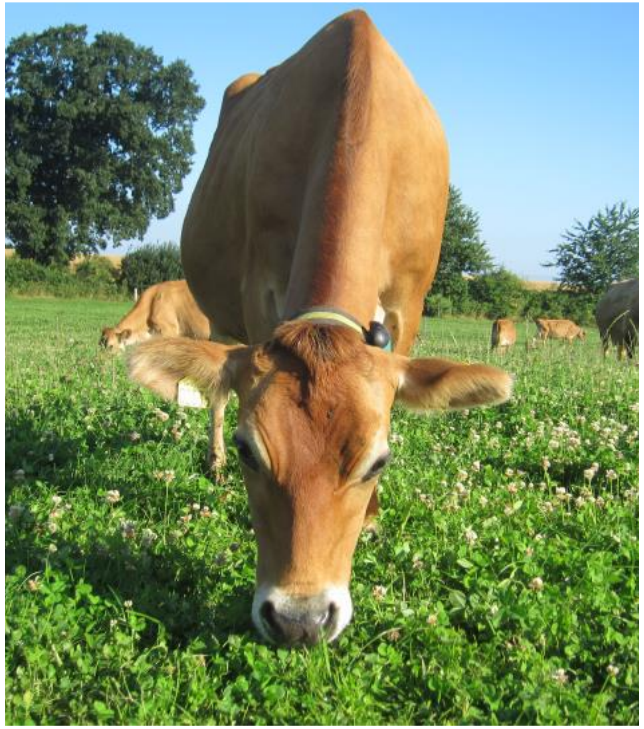


All year indoor
(silage based
no grazing)

Intermediate
(<50% dry matter intake from pasture; >25% concentrates)



Pasture based
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Lorenz H, Reinsch T, Hess S, Taube F 2018. Is low-input dairy farming more climate friendly? A meta-analysis of the carbon footprints of different production systems. Journal of Cleaner Production. DOI:10.1016/j.jclepro.2018.11.113

Meta study of pasture based compared to all year indoors milk production with respect to Product Carbon Footprint on the base of over 100 inter-national published scientific papers

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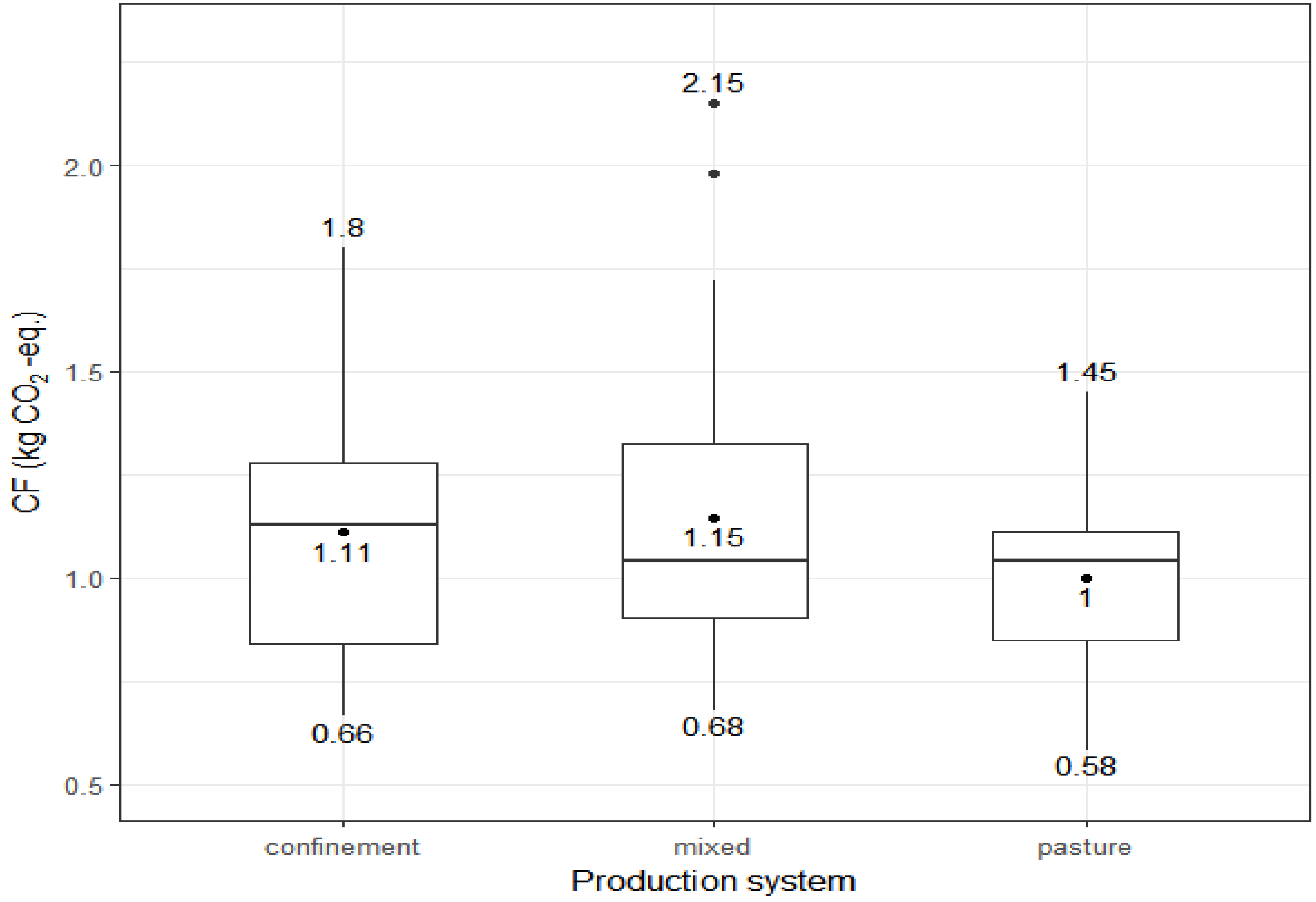

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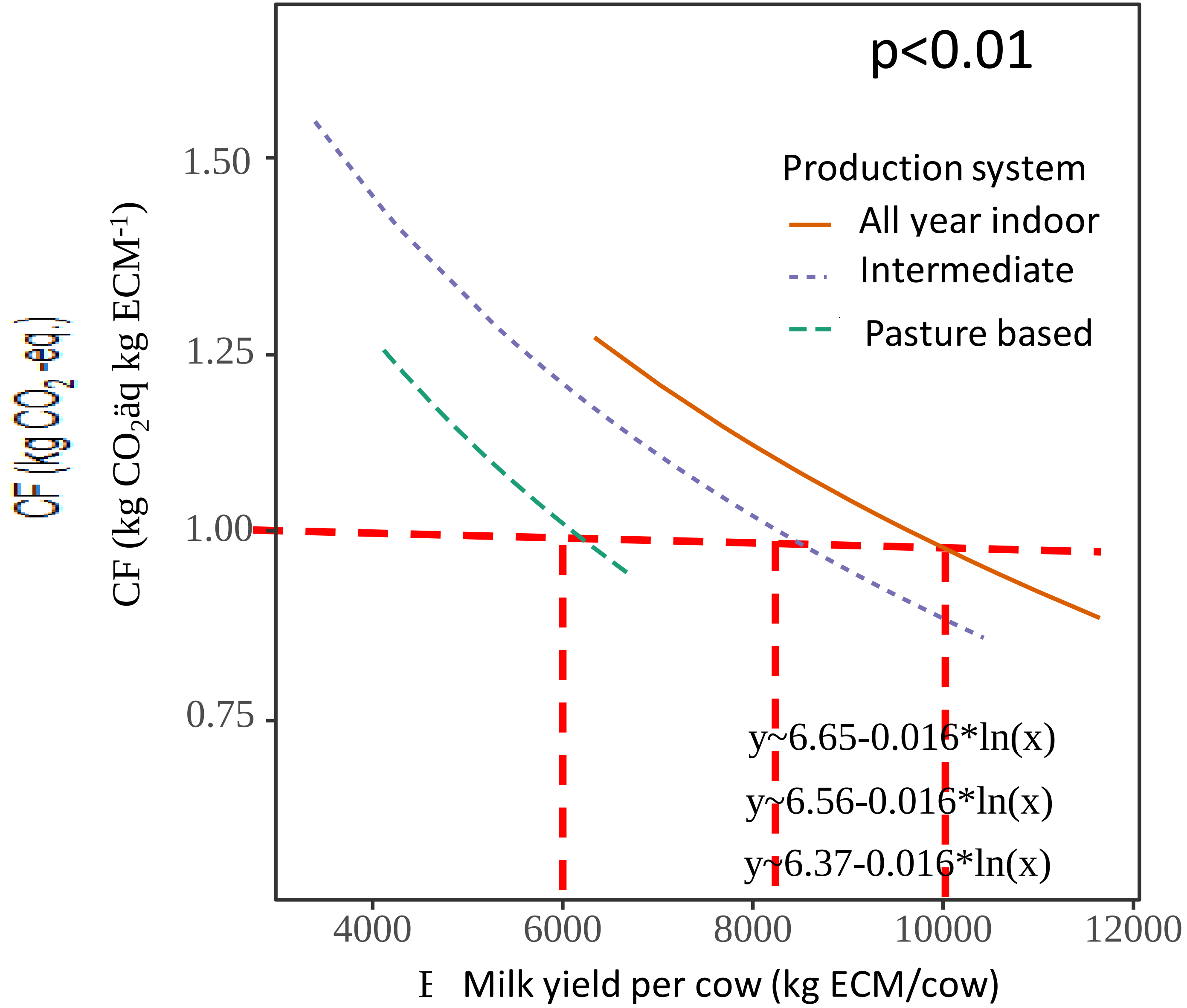

Herd average performance is of great importance for climate relevance of the respective husbandry system

Lorenz H, Reinsch T, Hess S, Taube F 2018. Is low-input dairy farming more climate friendly? A meta-analysis of the carbon footprints of different production systems. Journal of Cleaner Production. DOI:10.1016/j.jclepro.2018.11.113

Hypothesis

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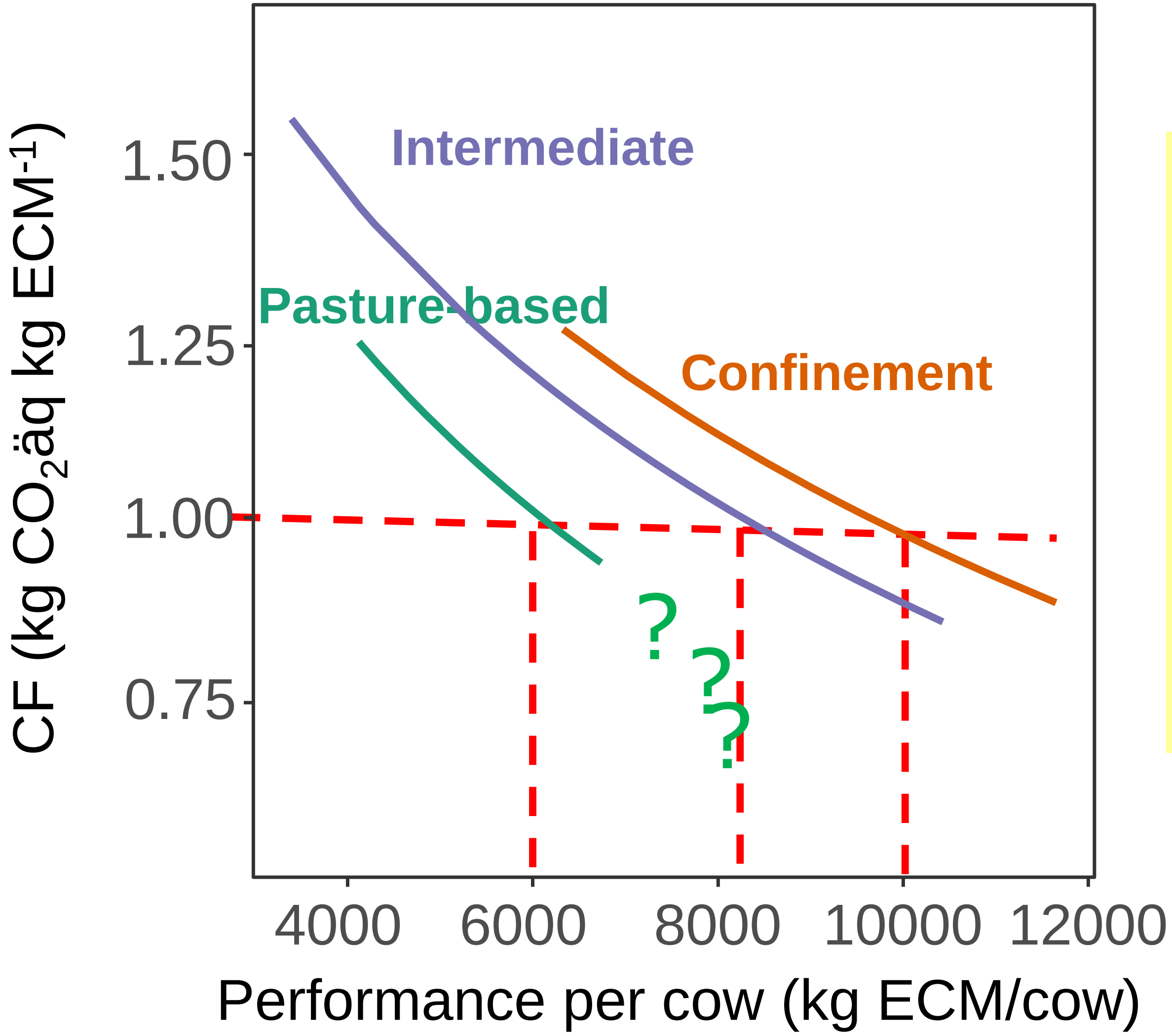

Hypothesis

The combination of an moderate increase in milk yields per cow, reduced GHG-emissions and ley carbon sequestration ends up in lowest PCF/PNF milk from ICLS

(Lorenz et al., 2018)

Aim of the here presented project carried out on farm level:

Can the reintroduction of a dairy herd on a former specialized all arable farm reduce theses challenges and produce milk profitably in a climatic friendly way?


https://www.dailymail.co.uk/sciencetech/article-7386473/Udderly-ridiculous-Scientists-fitting-cows-m

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Tuesday, Jul 4th 2023 7AM 13°C 10AM 17°C 5-Day Foreca

MailOnline

Udderly ridiculous! Scientists are fitting cows with methane-detecting harnesses to measure the potent greenhouse gas in their flatulence

It is hoped that feeding the animals a new diet will reduce their emissions and could lead to a breakthrough in climate management.

Scroll down for video

© DPA/PA Images

+10 View gallery

Pictured, two of the cows standing on a pasture of the Lindhof sample with their unique measuring devices. The ruminants produce methane, a climate-damaging greenhouse gas

The interdisciplinary project: "Eco-efficient pasture-based milk production" started 2016 at Kiel University's organic research farm Lindhof in Northern Germany.

The project focusses on a whole-farm approach to analyse the potential of pasture-based milk production on grass-clover leys to strengthen sustainability of an organic arable crop rotation.

In 2015 Lindhof's low input herd of suckler cows + followers (0,4 LU/ha) was replaced by a spring calving herd of dairy cows (0,9 LU/ha).

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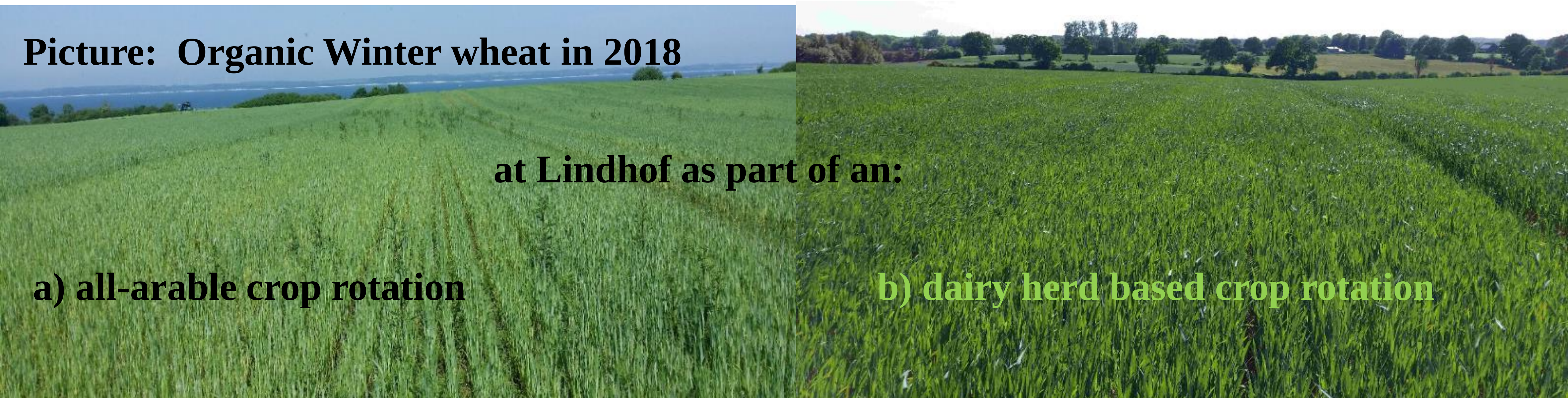


“Eco-efficient milk production” Lindhof

Aim: Maximization of milk production from grazing at a reduced input of concentrates (770 kg/cow/year)

What we do:

Grazing of 2year lasting multi species grass clover leys (perennial rye-grass + white + red clover + birdsfoot trefoil + chicory + lancelot plantain + carravay)

Rotational grazing, after each milking allowance of very young fresh grass/clover , at a growing height of 8 cm based on platemeter readings

Grazing from beginning of March – to mid November (Grazing period: 275 days/year)

Seasonal-calving from end of January - mid April

Herdsize: 110 (Jerseys and Crossbreeds with EBI and Red Angeln Cattle)

First calving at an age of 23.5 month and a

replacement rate of only 18.3 %

No additional N-fertilisation to the grass clover,
all manure is transferred to arable crops)

Selfsufficiant with concentrates (Triticale + Faba beans)

Actual performance: 6720 kg/cow with 5.2 fat + 3.86 protein = 7829 kg ECM/cow

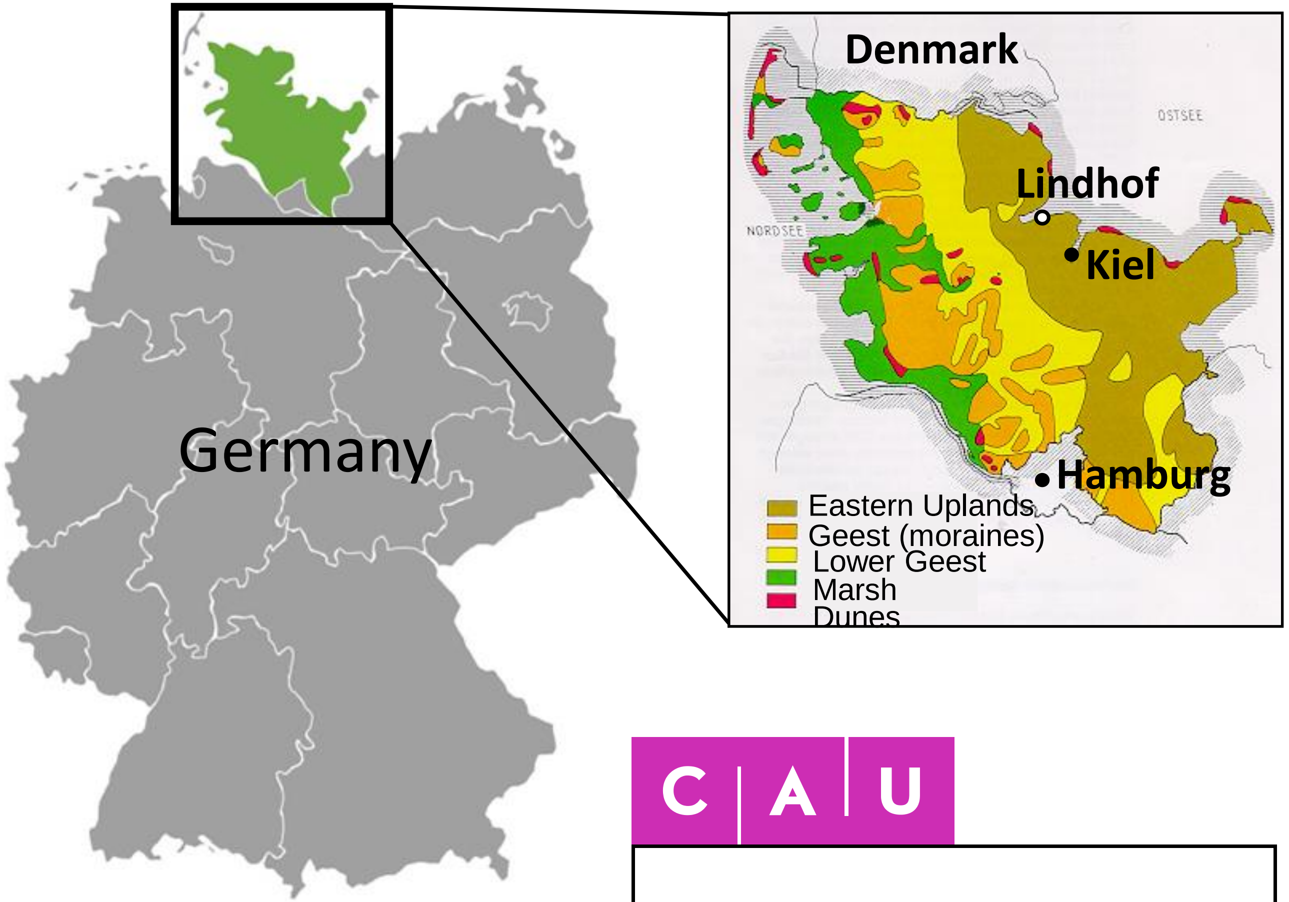
“Eco-efficient milk production” Lindhof

Reintroduction of grazing for dairy cows on an organic mixed farm in Northern Germany

Farm Area: 182.0 ha
production area: 159.3 ha
arable land 110.9 ha
perm. grassland (intens.) 6.9 ha
wet perm. grassland with management-restrictions 41.5 ha

100 Dairy cows on 52 ha grass clover leys
2 x 20 replacement heifers
+ 2 x 30 beef heifers on permanent grassland

Precipitation: **785 mm p.a.**
Temperature: **average: 8.7 °C**
Soil type: **sandy loam, loamy sand**



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Faculty of Agricultural and Nutritional Sciences

Table 1: Tab 1 Economic results and nitrogen balance (2019/20) of the experimental farm Lindhof compared to the average of 356 dairy farms consulted by the chamber of agriculture of Schleswig-Holstein

Milk production including Heifer rearing	**Unit**	**Lindhof**	**Average of 356 BZA full evaluated establishments in SH.**
Production technology			
Cow herd	number	94	166
Live weight	kg/cow	470	670*
Milk yield ECM	kg ECM/cow	7,007	9,433
Milk production natural	kg/cow	5,728	9,257
Milk per kg live weight	kg ECM/kg LG	14.90	14.08
Fat plus protein	kg/cow	592	702
Fat	%	5.59	4.2
Protein	%	3.99	3.45
Concentrates/cow/year	t/cow	0.80	2.81
Concentrated feed/kg ECM milk	g/kg ECM	120	295
Milk production per ha MFA on farm**	kg ECM/ha FA	10,946	14,866
Calculated forage performance according to BZA, ((maintenance covered by forage)	kg ECM/cow	5,284	3,767
Forage performance according (maintenance shared by all fodder sources	kg ECM/cow	5,865	5,519
Forage performance, proportion of total ration	%	75.41	39.93
Adjusted reproduction rate	%	18.20	33.40
First calving age (LKV annual report 2020)	Months	23.9	28.4[a]
Calving interval (LKV annual report 2020)	days	362	400[a]
Costs for vet, medicines + hoof care	ct/kg ECM	1.48	1.64
Feed costs per kg ECM milk produced***	ct/kg ECM	16.81	22.12
Forage costs (pro rata)	ct/kg ECM	12.17	13.35
Concentrated feed costs (pro rata)	ct/kg ECM	3.83[α]	8.77
More metrics			
Mineral N fertilizer input (kg/ha HFF)	kg N/ha HFF	0	99
N balance[b] (sub-farm milk produced)	kg N/ha HFF	88	149

* Estimated value based on the average of the breeds, **without area requirements for imported feed;
*** incl. rearing replacement heifers, [a]Farms in the same region, [b]Farm-gate N balance of the sub-farm milk production, [α]from organic production at a 63% higher price
Abbreviations: SH = Schleswig-Holstein, ECM = energy-corrected milk, MFA = main forage area, BZA = branch accounting, source: LK SH 2020

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How climatic friendly is the presented system ?

Methane Emission and Milk Production From Jersey Cows Grazing Perennial Ryegrass–White Clover and Multispecies Forage Mixtures

(*Agriculture* 2021, 11 (2), 175)

In vivo experiment: Main results

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Table 3. Forage characteristics, milk production, target daily herbage availability, DM intake, herbage utilization, methane emissions, and body weight (BW) variation of dairy cows grazing on binary and diverse mixtures. Abbreviations are as follows (sorted alphabetically): ADF: acid detergent fiber, CP: crude protein, DHA: daily herbage allowance, DMI: dry matter intake, ECM: energy-corrected milk, FUE: forage use efficiency, HM: herbage mass, ME: metabolizable energy, NDF: neutral detergent fiber, and NEL: net energy for lactation.

	P1 (2–8 May 2019)		P2 (15–30 August 2019)	
	Binary	**Diverse**	**Binary**	**Diverse**
	Mean (SEM)	**Mean (SEM)**	**Mean (SEM)**	**Mean (SEM)**
Forage characteristics				
HM (kg DM ha^{-1})	2460 (177) ^{Aa}	2157 (68) ^{Aa}	677 (95) ^{Bb}	1218 (151) ^{Aa}
OM digestibility	87.6 (0.25) ^{Aa}	84.4 (0.17) ^{Ba}	80.2 (0.36) ^{Ab}	77.9 (0.44) ^{Bb}
ME (MJ kg DM^{-1})	12.5 (0.03) ^{Aa}	12.1 (0.01) ^{Ba}	11.3 (0.09) ^{Ab}	11.1 (0.05) ^{Bb}
NEL (MJ kg DM^{-1})	7.7 (0.01) ^{Aa}	7.5 (0.01) ^{Ba}	6.9 (0.06) ^{Ab}	6.7 (0.03) ^{Bb}
Chemical composition (g kg^{-1})				
CP	11.5 (0.52) ^{Ba}	15.6 (0.14) ^{Aa}	18.5 (0.79) ^{Bb}	20.3 (0.51) ^{Ab}
NDF	35.5 (0.29) ^{Ba}	38 (0.30) ^{Aa}	49.9 (0.66) ^{Bb}	45.3 (0.46) ^{Ab}
ADF	16.6 (0.20) ^{Ba}	19.5 (0.17) ^{Aa}	22.8 (0.40) ^{Bb}	26.7 (0.33) ^{Ab}
Fat	2.7 (0.1) ^{Bb}	3.1 (0.05) ^{Aa}	4.1(0.08) ^{Aa}	3.6 (0.06) ^{Ba}
Milk production				
Days in milk	49 (28)	49 (28)	154 (26)	154 (26)
Milk yield (kg cow^{-1} day^{-1})	23.4 (0.77) ^{B,a}	24.9 (0.86) ^{A,a}	18.6 (0.71) ^{B,b}	19.8 (0.66) ^{A,b}
ECM yield (kg cow^{-1} day^{-1})	29.4 (0.91) ^{B,a}	30.3 (0.98) ^{A,a}	22.1 (0.61) ^{B,b}	23.5 (0.64) ^{A,b}
DMI (kg DM cow day^{-1})[1]	16.7	16.8	11.5	11.5

In vivo experiment: Main results

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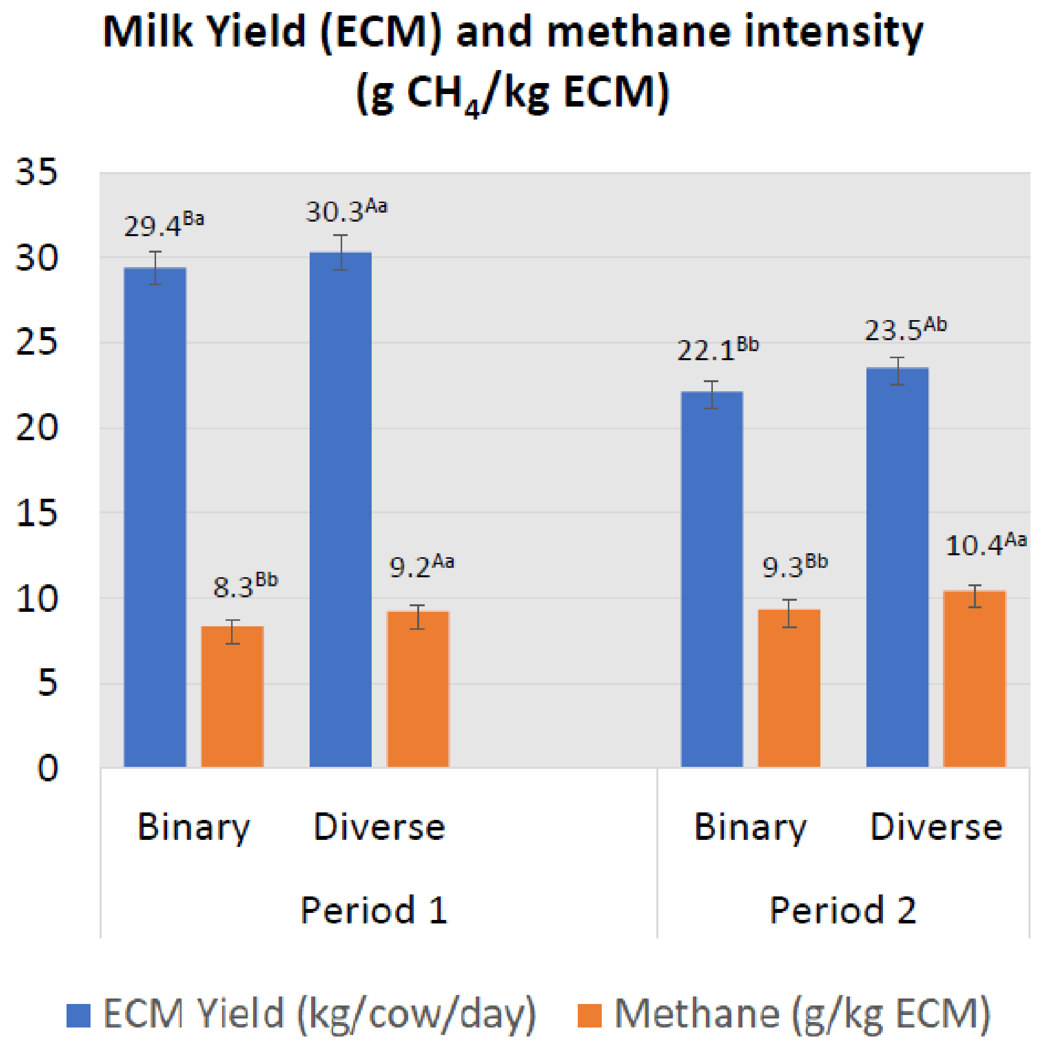

[A,B] Differences between treatment, [a,b] differences between the periods,

Performance of pasture-based system in the world

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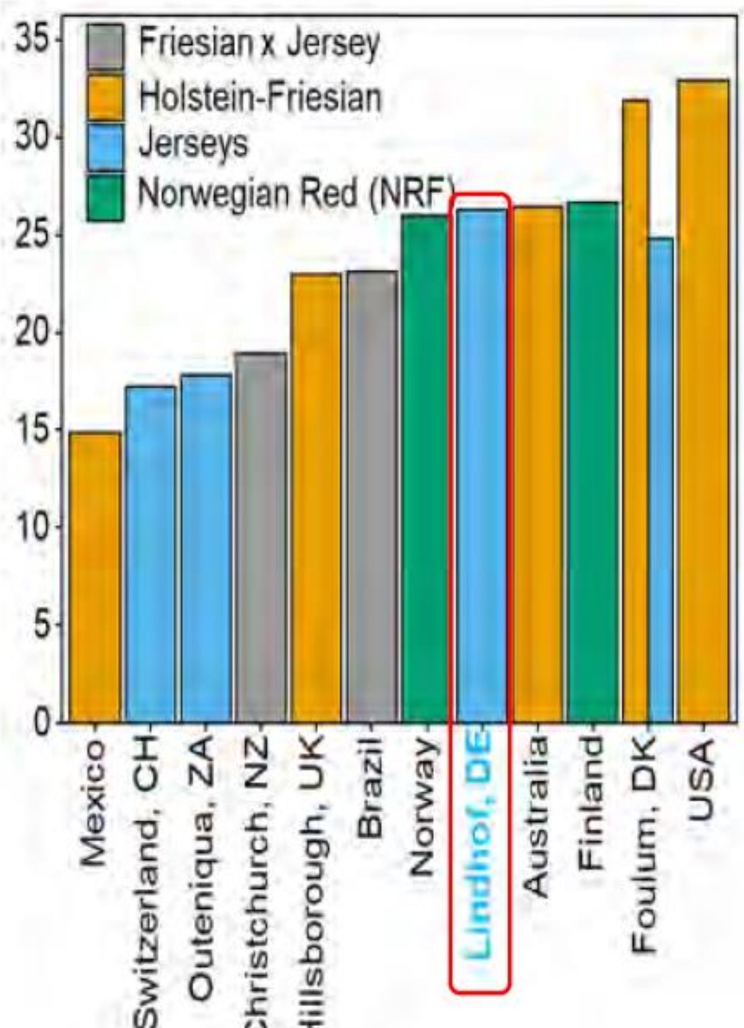
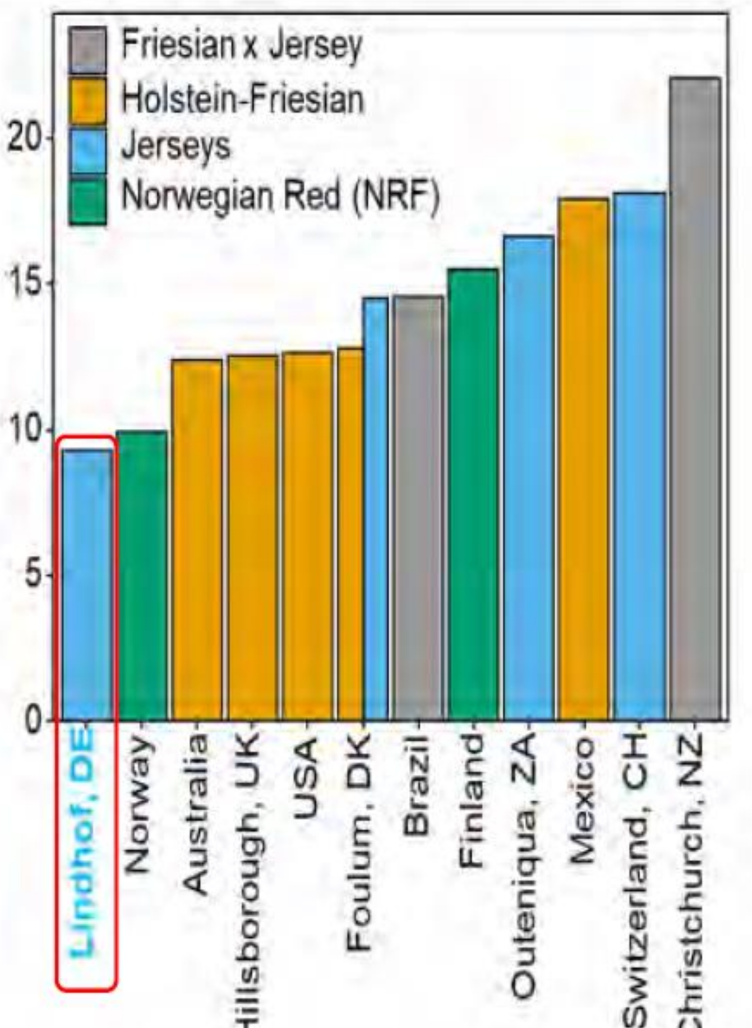
ECM (kg/cow/day)



CH_4 intensity (g/kg ECM)



- Lindhof system(ICLS) shows high performance and low environmental impact when compared with other pasture-based systems.

Grassland Management : Fresh grass can lead to less methane gas
Study of Wageningen University 2022 by Cindy Klootwijk et al

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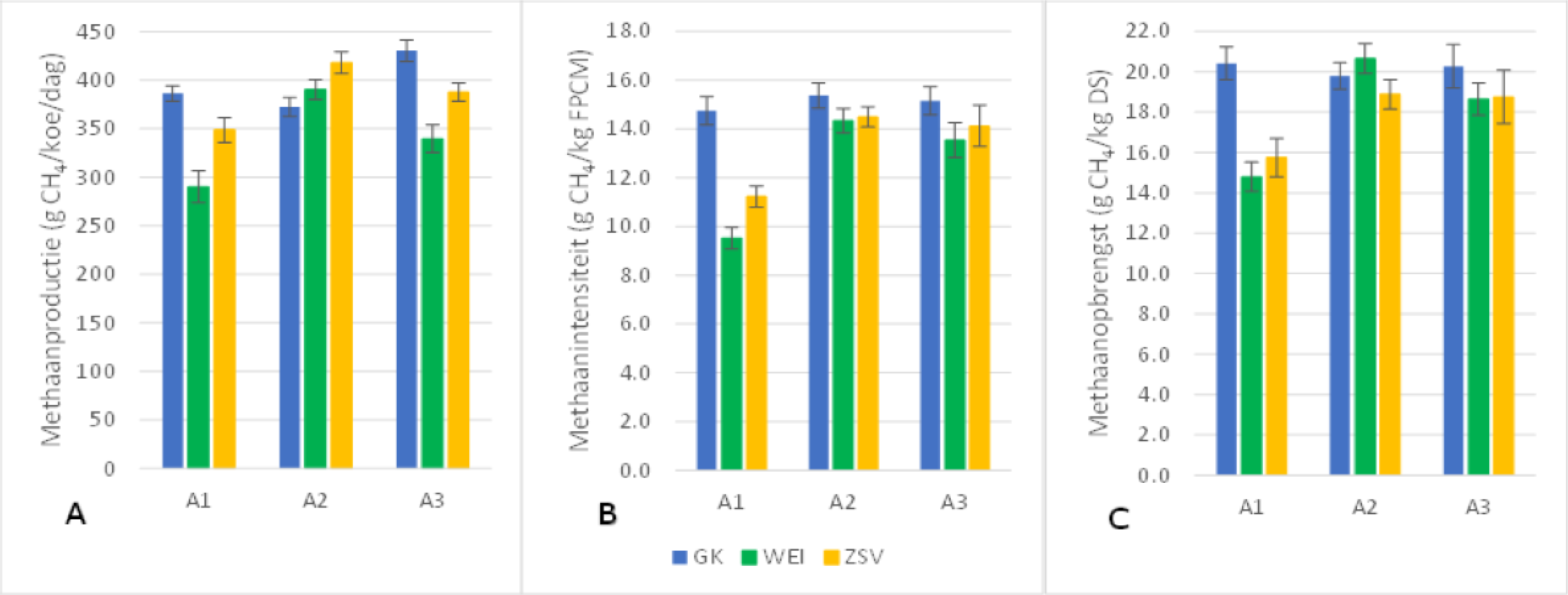


Figuur 3.3 *Gemiddelde CH_4 emissie per behandeling (GK in blauw, WEI in groen en ZSV in geel) per periode (A1, A2, A3) tijdens proef A in 2021, uitgedrukt als CH_4 productie per koe per dag (grafiek A), CH_4 intensiteit per kg FPCM (grafiek B) en CH_4 opbrengst per kg DS opname (grafiek C), inclusief de standaard error (zwarte lijnen).*

GK = a basic ration of unlimited grass silage fed in the barn **(Wei) unlimited grazing,**

ZSV summer barn feeding with unlimited fresh grass in the barn

Material and Methods
Lindhof: comparsion of PCF to 3 alternative farms in the same region

On 4 different structured dairy farms in the same area of Schleswig-Holstein:

Forage yield was determined using a rising plate meter and hand sampling

Forage quality was estimated using NIR-spectroscopy.

Measurement of N_2O emissions were carried out using the closed chamber method.

Nitrate leaching to the groundwater was determined by sampling soil water with ceramic suction cups continuously during the winters 2016/17 to 2018/19. and analyzing it for NO_3-N-concentrations.
The volume of drainage water was calculated by a general climatic water balance model.

Material and Methods

The Product Carbon Footprint (PCF) for milk production was calculated using measured data for N_2O as direct and N-leaching as indirect source for N_2O-emissions.

Additional **indirect N_2O emissions from NH_3 volatilization in the barn were calculated according to** *Burgos et al., 2010*.
The **emission factors for NH_3 volatilization from grazing animals were based on the review analysis** of *Sommer et al., 2019*.
Other **gaseous N-emissions during manure application were evaluated according to the IPCC guidelines.**

Methane emissions from ruminal digestion were calculated according to *Schils et al., 2007*.

PCF-Milk of Lindhof is compared to 3 contrasting specialised dairy farms from the same region:

1) Conventional: all year indoors: 11170 kg ECM cow^{-1} $year^{-1}$

2) Conventional: restricted grazing: 9484 kg ECM cow^{-1} $year^{-1}$

3) Organic: low input / full grazing 6060 kg ECM cow^{-1} $year^{-1}$

Results

Tab 2: Chosen Parameters with relevance to environment of the organic mixed-farm Lindhof in comparison to 3 different specialized dairy-farms of the same region (average of 2 years. abreviations ECM = Energiecorrected Milk. FA= Forage area on farm)

Parameter Dairy production including replacement	Unit	Organic mixed farm Lindhof	organic-low-input full grazing on permanent pasture	Intensive 80 days of grazing (conventional)	Intensive all year housed (conventionell)
Milk yield ECM	kg ECM/cow	6867	6060	9484	11817
Concentrates/cow/year	kg/cow	900	200	2400	3100
Milkproduktion per ha Forage Area on farm**	kg ECM/ha FA	10394	7420	11512	15817
Fodder Area needed to produce 1 kg ECM including production of concentrates	m^2/ kg ECM	1.3	1.4	1.2	1.2
N_2O -Emissiones per ha FA	kg N_2O/ha	1.5	2.3	7.8	6.2
Nitrat-N-leaching to the groundwater per ha FA	kg NO_3^--N/ha	9	16	48	25
Methane-Emission Manure storage	kg CO_2/ha FA	777	889	2491	3225
Soil-carbon sequestration	kg CO_2/ha FA	-2063	-1725	-1327	-891
N-Balance per ha FA (Milk + Heiffers)	kg N/ha	50	94	190	220
Carbon-Footprint (PCF) per kg ECM-h	kg CO_2 / kg ECM	0.63	0.92	1.22	1.08

(Source: Reinsch T. Loza C. Malisch CS. Vogeler I. Kluß C. Loges R. Taube F 2021. Toward Specialized or Integrated Systems in Northwest Europe: On-Farm Eco-Efficiency of Dairy Farming in Germany. Front. Sustain. Food Syst. 5. 614348. https://doi.org/10/gj68j4)

Conclusions

High milk yields at very low costs and almost no nitrate losses combined with increased yields of succeeding cereal crops show the capability of a rotational ley grazing systems to be economically competitive exhibiting simultaneously reduced environmental burdens.

The findings underline the strength of ruminant-based crop-livestock systems as a tool towards ecological intensification under the temperate conditions of Northern Germany.

Grazing of energy rich young grass leads to low methane emissions, in combination with a) a low demand for energy and b) a high soil carbon-sequestration grazing is a strategy for climatic friendly milk production

Outlook: Climate change potential of milk in comparison to milk-alternative drinks from the supermarket

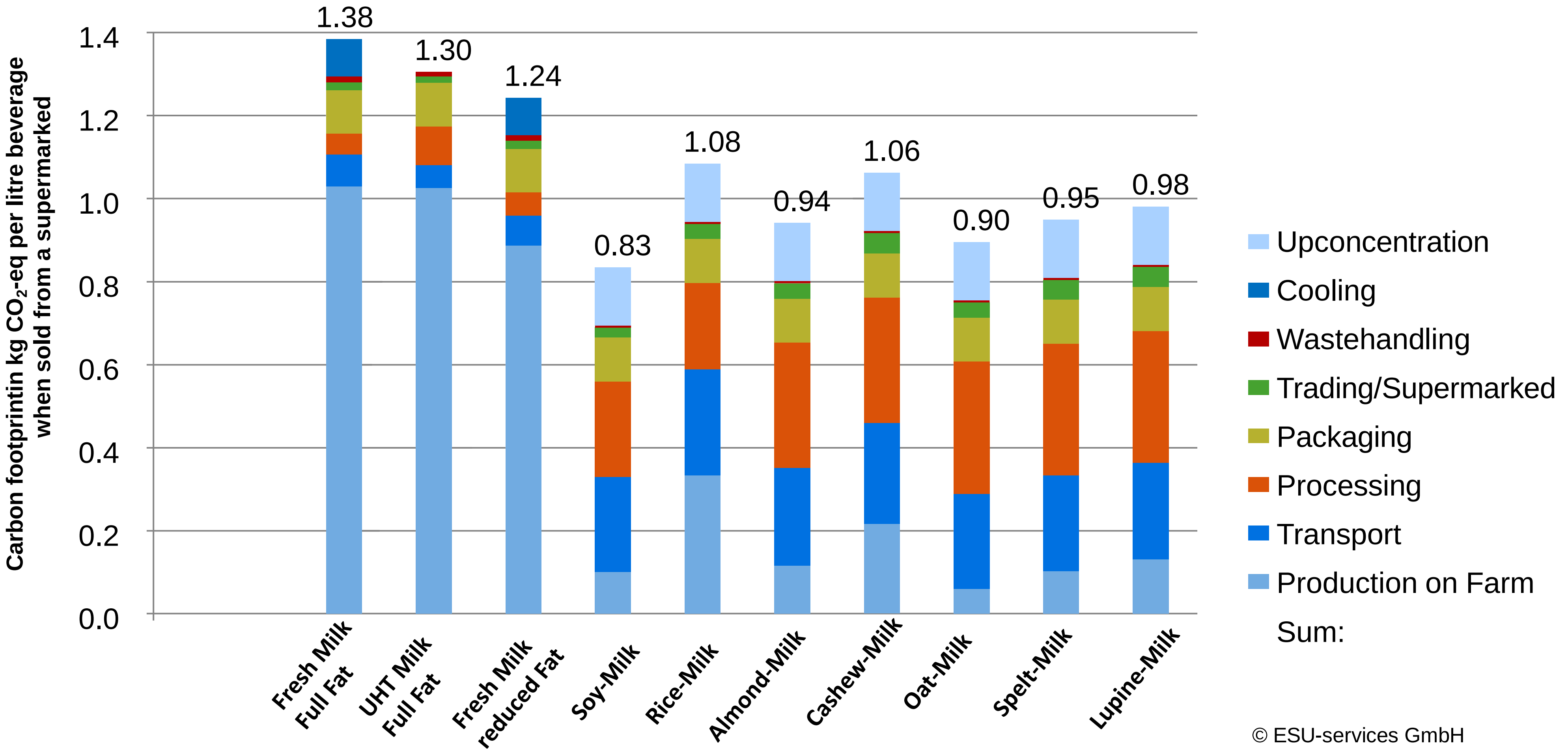
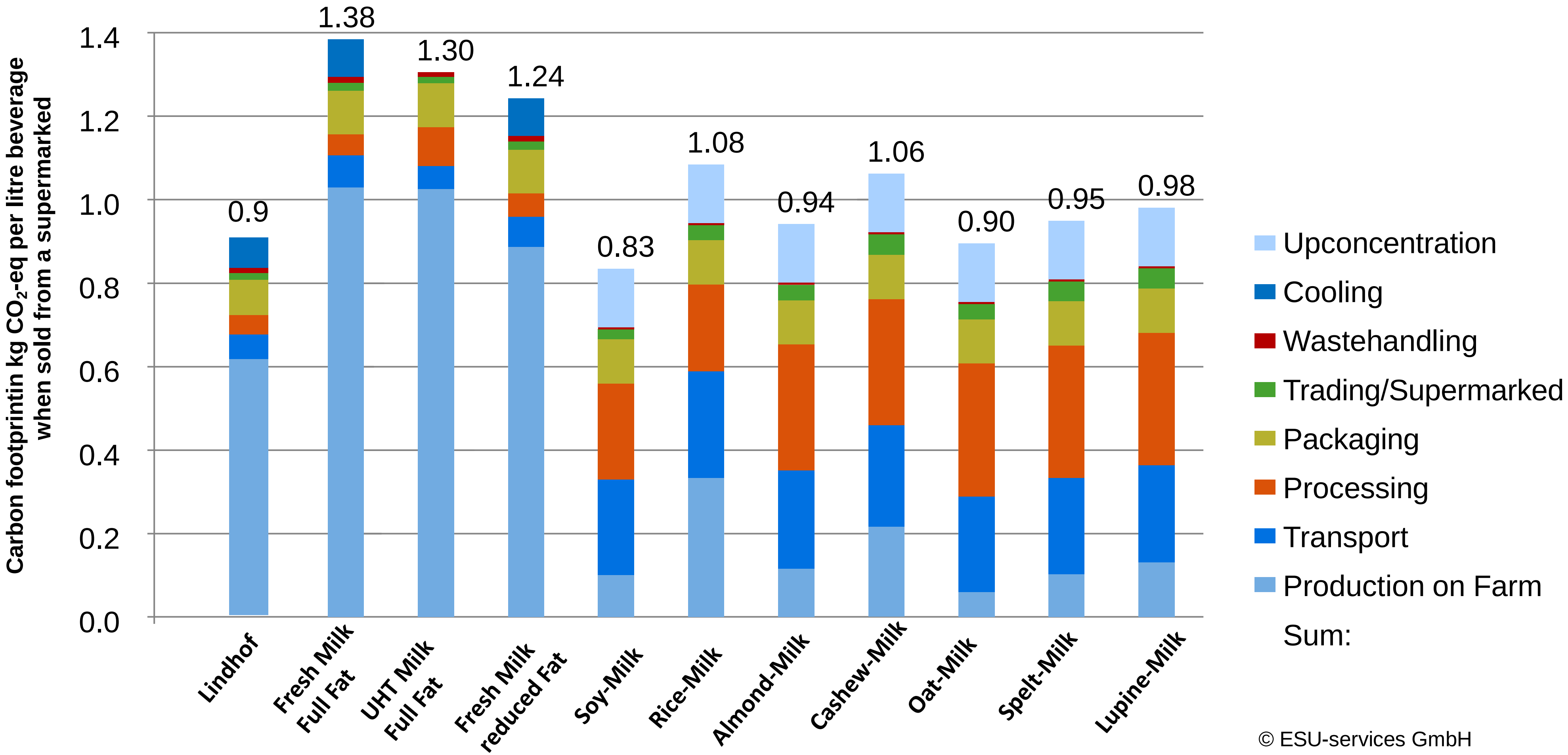


Fig. 5.6 Comparison of the various milk drinks and fortified drinks for the greenhouse effect (kg CO2-eq per liter ex supermarket, IPCC 100a, including additional influences from air transport

Maresa Bussa;Martina Eberhart;Niels Jungbluth;Christoph Meili (2020) Ökobilanz von Kuhmilch und pflanzlichen Drinks. ESU-services GmbH im Auftrag von WWF Schweiz, Schaffhausen, Schweiz, www.esu-services.ch/de/publications/

Outlook: Climate change potential of milk in comparison to milk-alternative drinks from the supermarket



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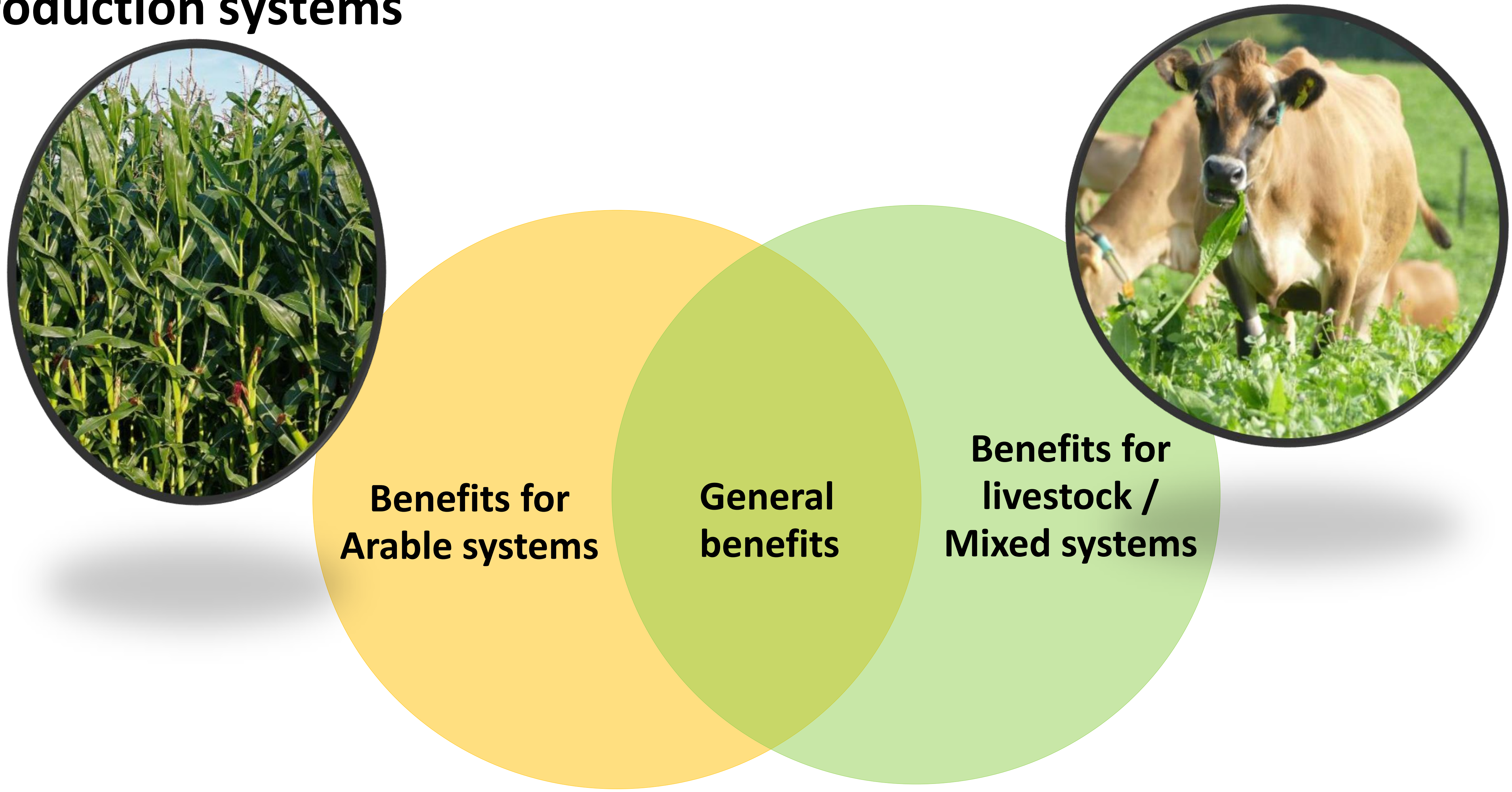
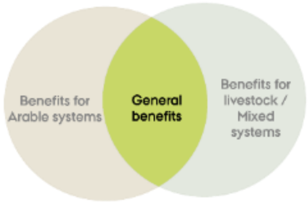
Thank you for your attention !!!

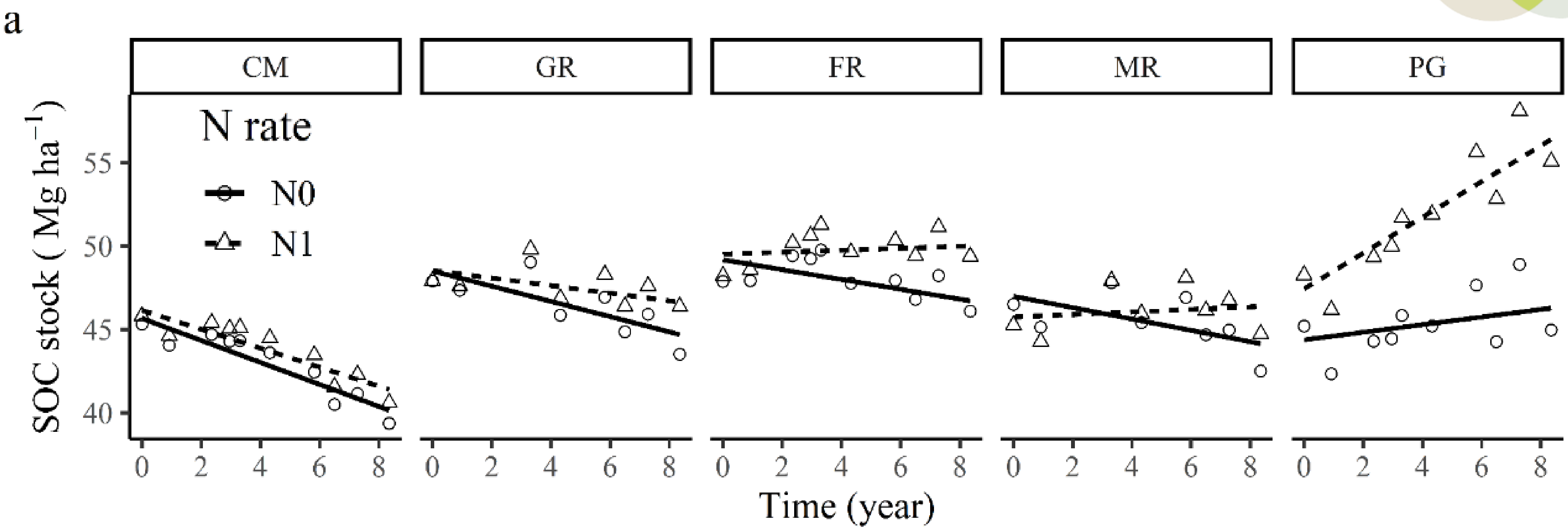
CAU

(Diverse) temporary Grasslands can provide benefits independent of production systems



Absence of grassland ley always results in C losses





CM: Continuous silage maize

GR: Grain rotation

FR: Forage rotation (1 year ley)

MR: Mixed rotation (1 year ley)

PG: Permanent grassland

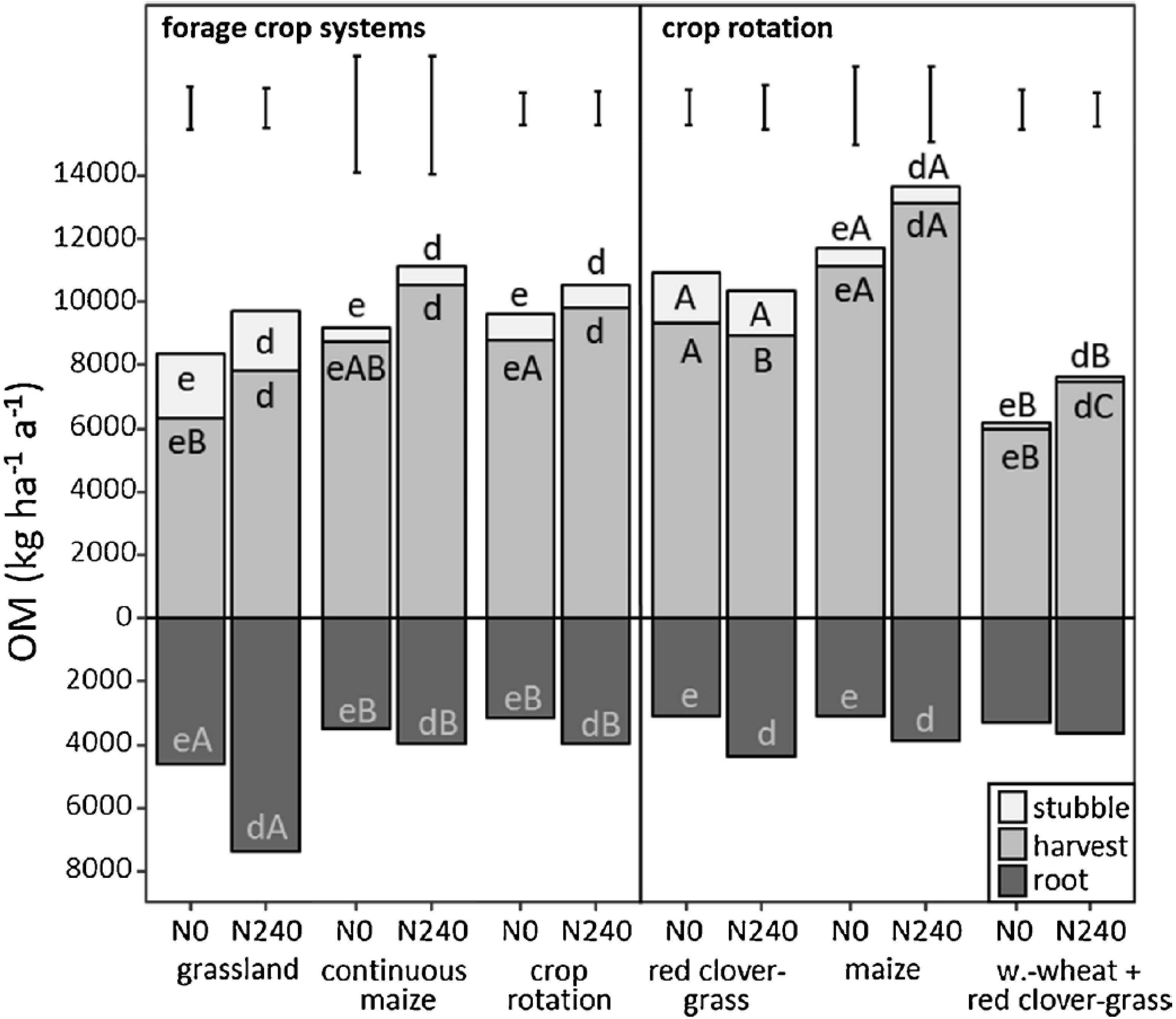
N0: unfertilized

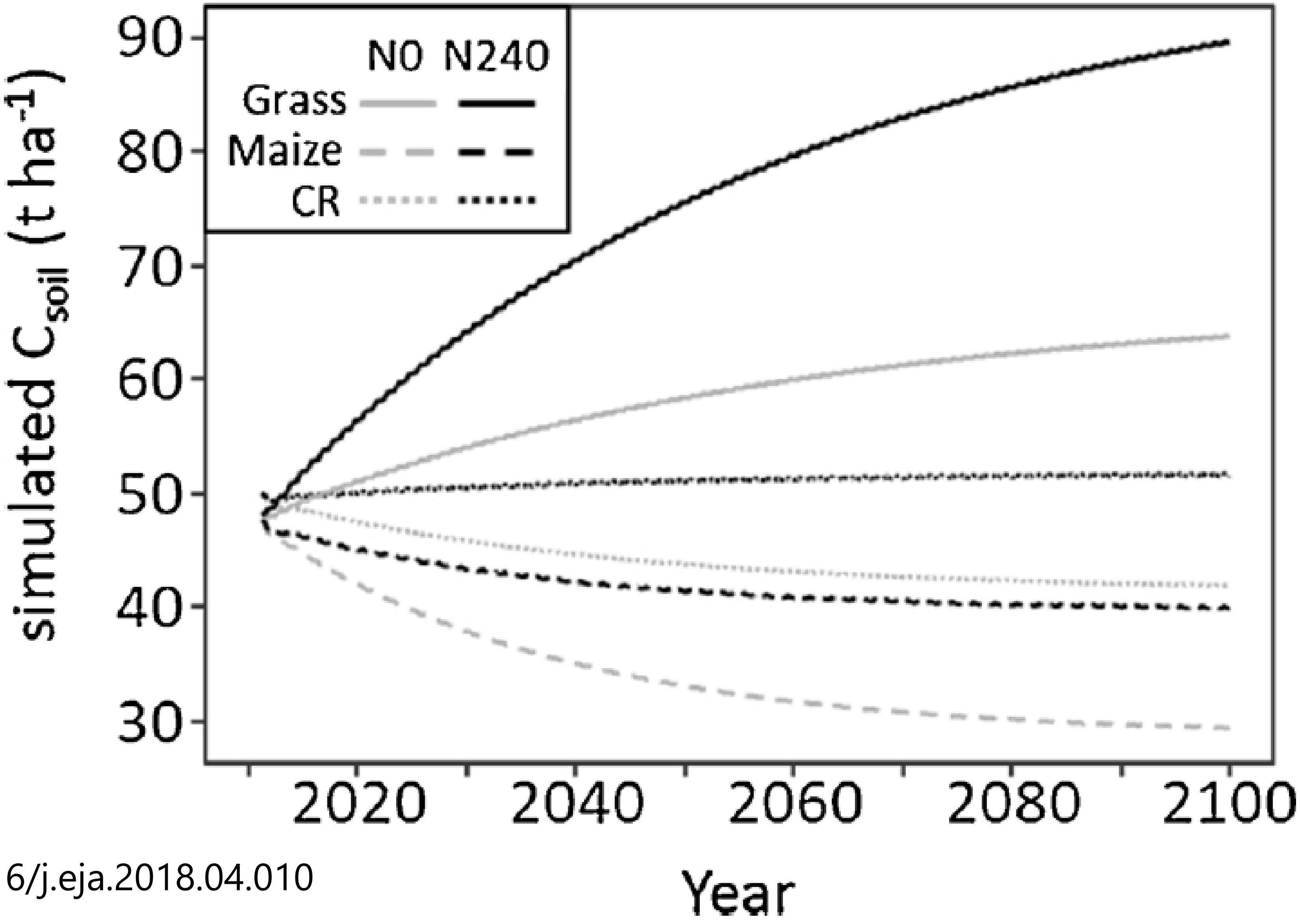
N1: 240 kg N to non-legumes

De los Rios *et al.*, (2022); 10.3390/agronomy12020338

Above- and belowground biomass formation in maize, Crop rotations and permanent grassland

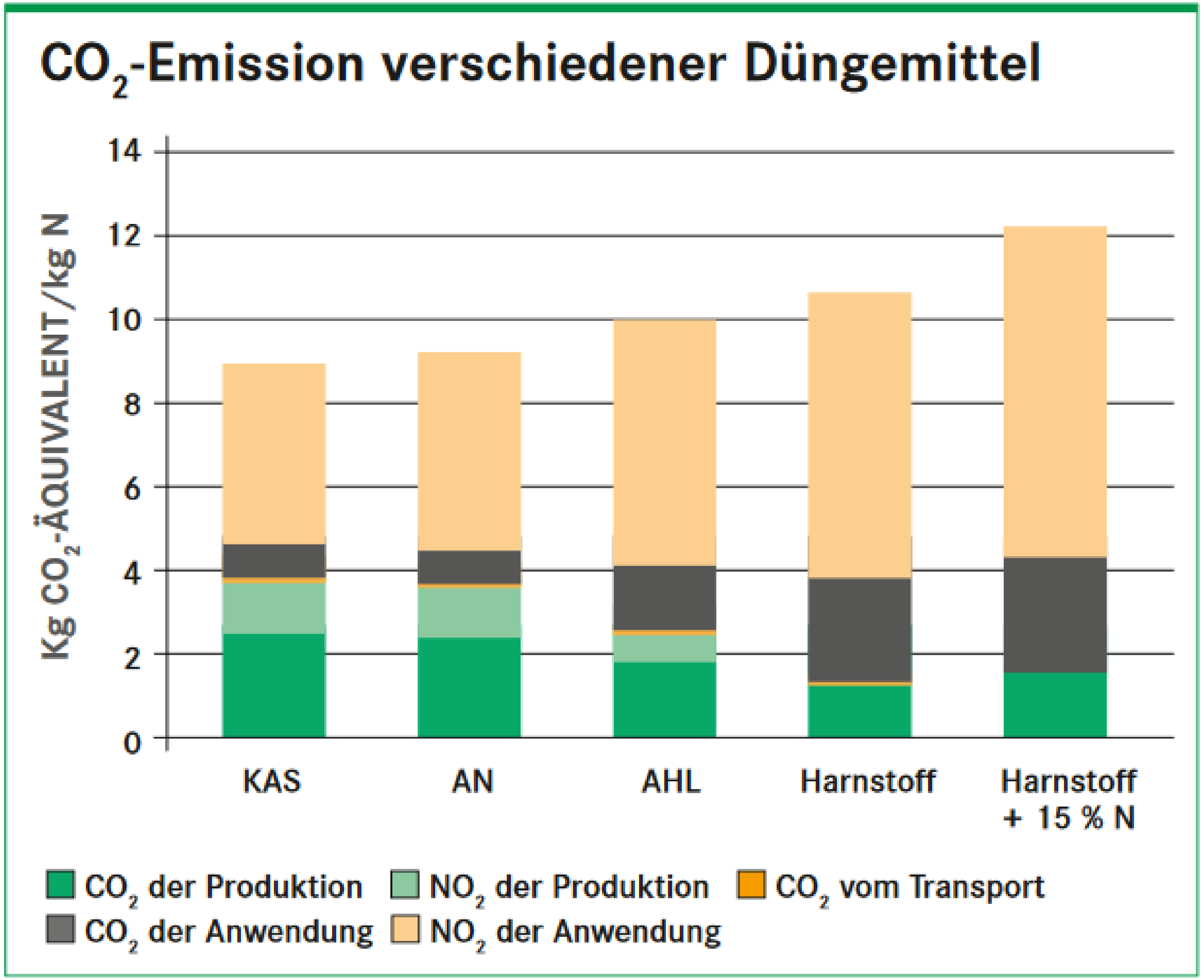
Loges et al, 2018: 10.1016/j.eja.2018.04.010





Loges et al, 2018: 10.1016/j.eja.2018.04.010

Weide hilft Mineral-N-sparen

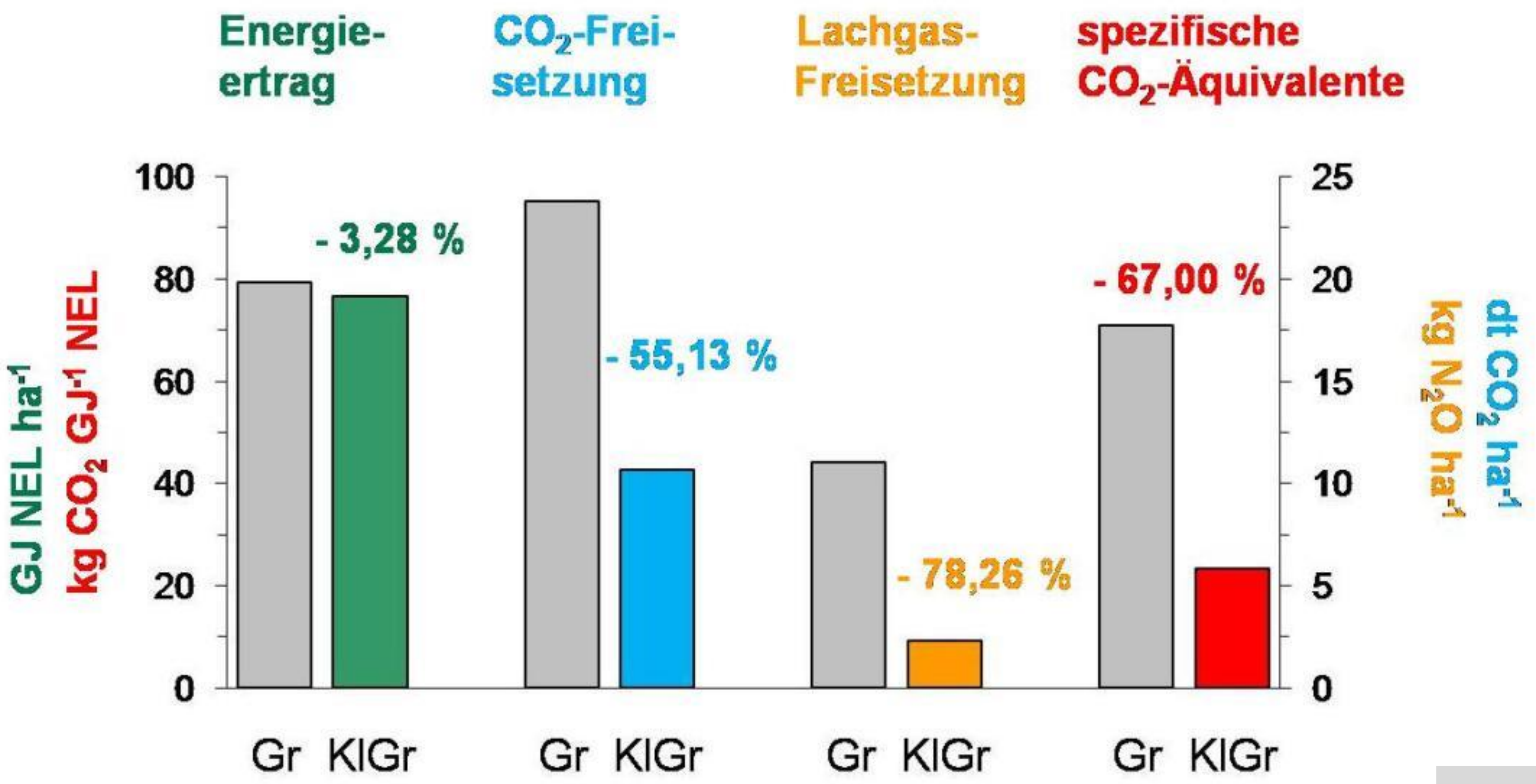


Herstellungsprozess stark endotherm, d. h. es wird viel Energie verbraucht (je kg NH_3-N etwa 1 l Öl-Äquivalente)

(WD des Bundestages 2018)

Heinzelmeier 2018

CO_2-Bilanz – Vergleich Ackergras –Luzerne-Kleegras



Standort	**Versuchsbetrieb Hohenschulen (Ackerzahl: ~50)**
Nutzung	**3 Schnittnutzung**
Gr	**Grasbestand, 360 kg N ha^{-1} über Mineraldünger (Kalkammonsalpeter)**
KlGr	**Luzerne-Kleegrasbestand, ohne N-Düngung**

Schmeer M, Loges R, Dittert K, Senbayram M, Horn R, Taube F (2014). Legume-based forage production systems reduce nitrous oxide emissions. Soil Tillage Res. 10.1016/

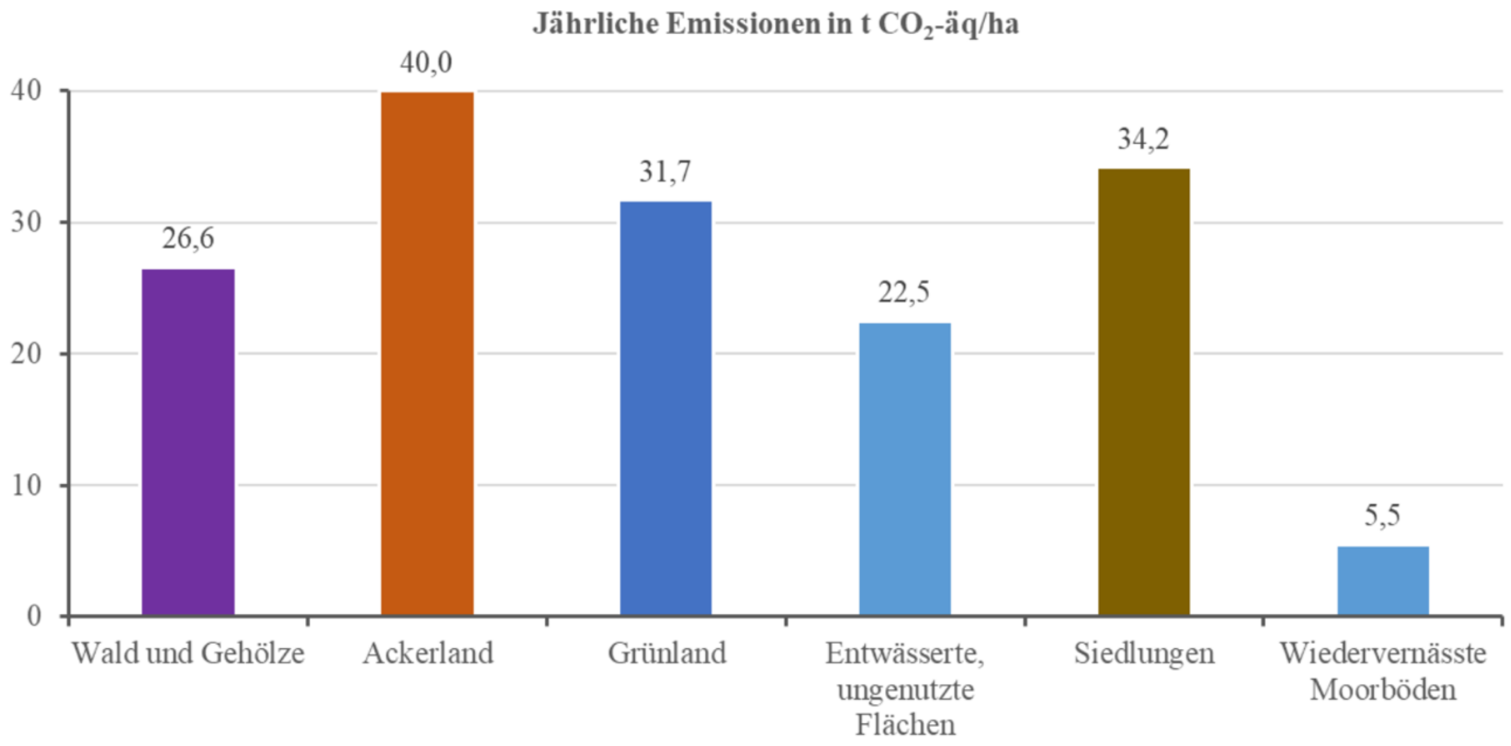
Carbon Footprint der Rindermast in Schleswig-Holstein (kg CO2äq/kg SG),

Reinsch et al 2019.

Milchviehkälber			Mutterkuh	
Rosé	**Färsen**	**Bullen**	**Färsen**	**Bullen**
9,5	23,6	13,2	30,4	23,3

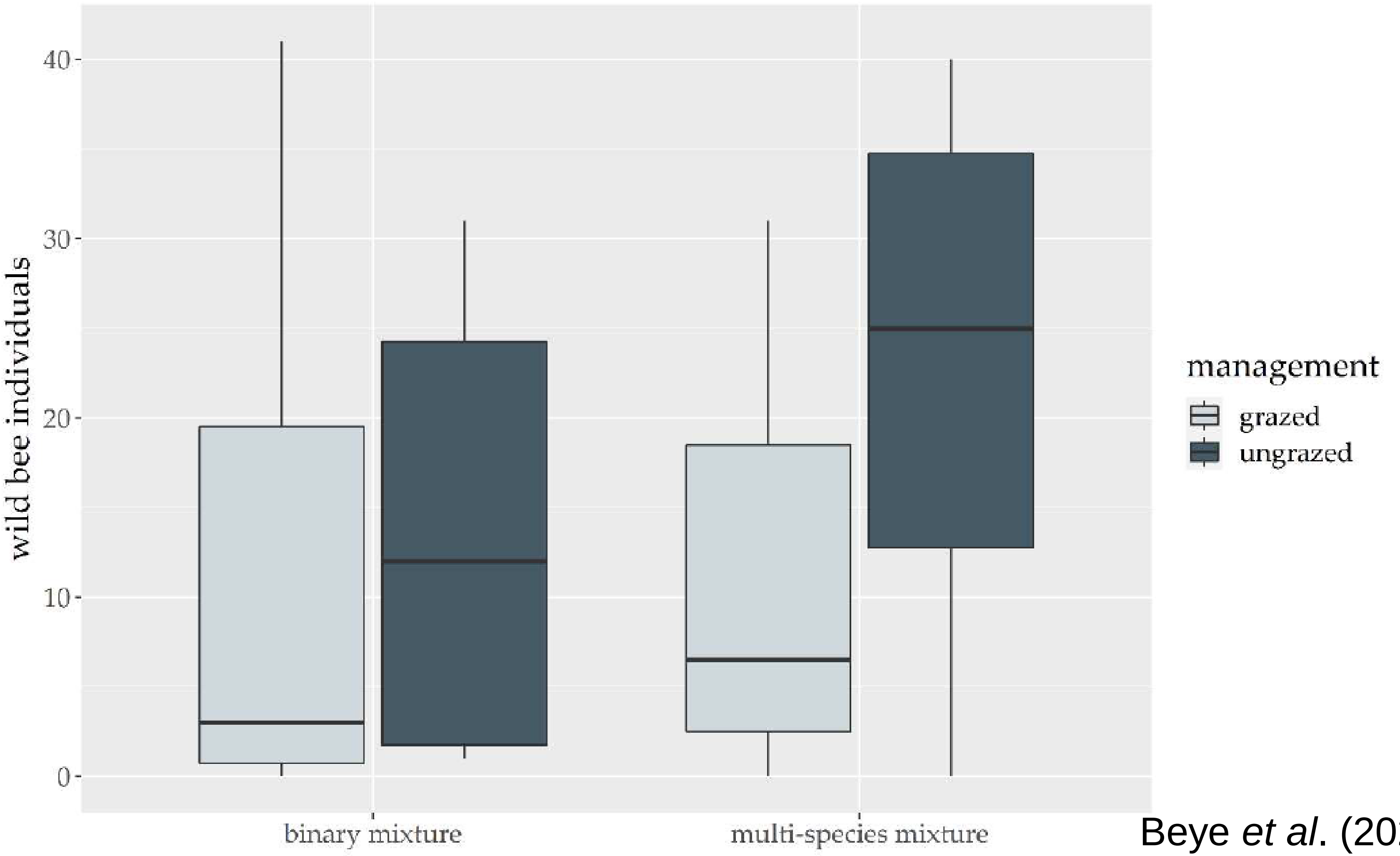
THG-Hotspot Moor

- CO_2, CH_4 (28), N_2O (298)
- 46,8 Mio. T CO_2-Äqu. / a
  - Gesellschaftliche Kosten von 2,8-8,6 Mrd. €/a (UBA, 2019)
- 1/3 der THG-Emissionen der Landwirtschaft
- Auf 1 Hektar können pro Jahr Ø 20 t CO_2 eingespart werden. (Isermeyer et al., 2019)



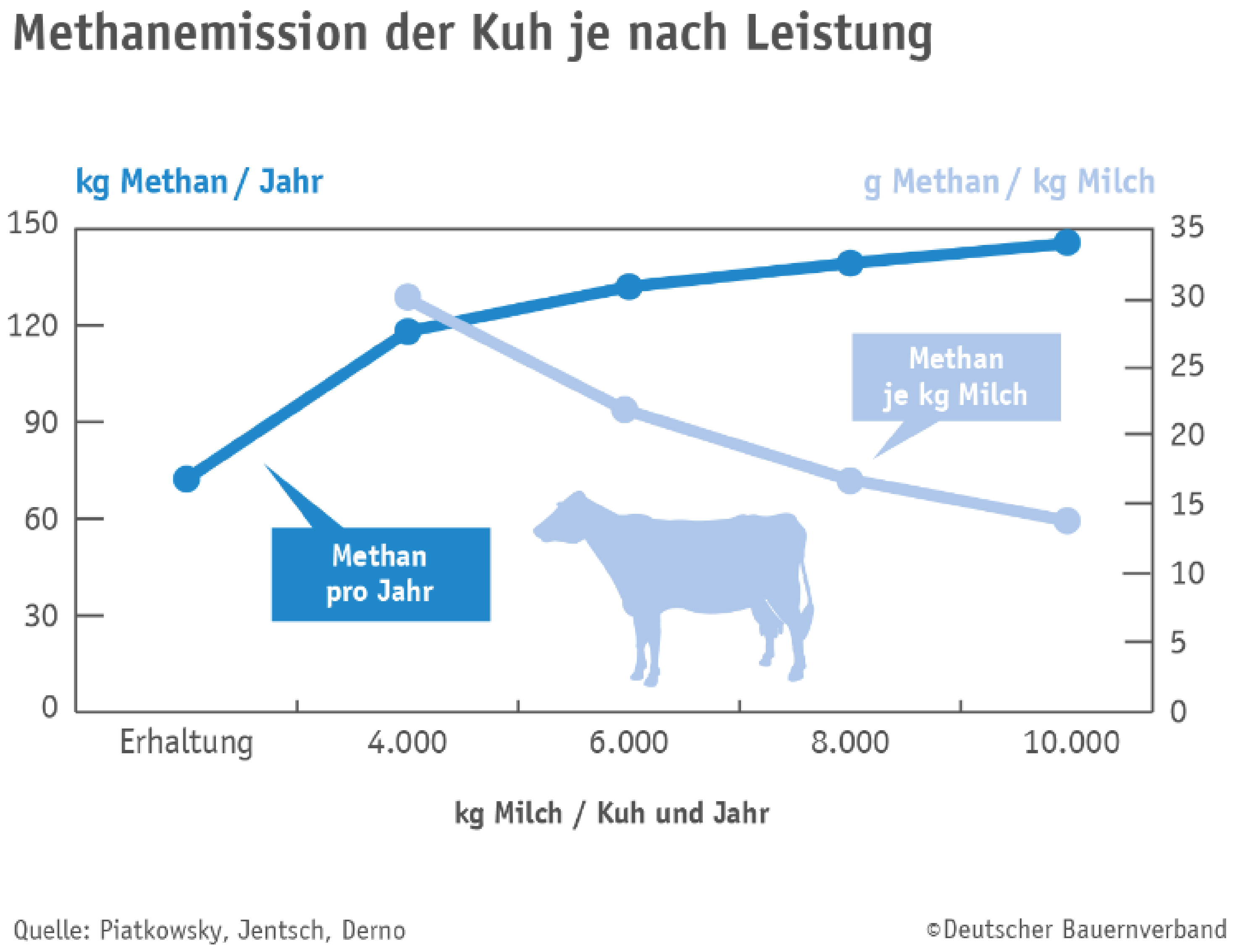
(Tiemeyer et al., 2020)

Especially grazed multispecies mixtures had high pollinator abundance



Beye *et al*. (2022)
10.3390/agronomy12051080

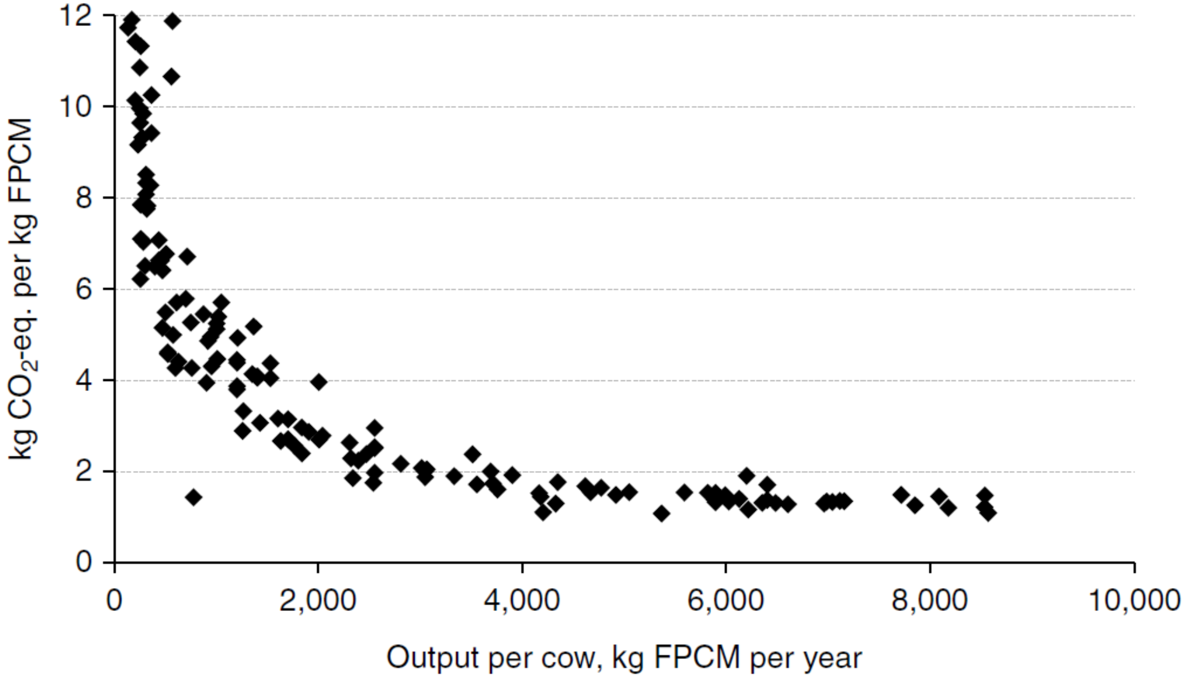
Abnahme der Methanemission je Kg ECM-Milch mit zunehmender Leistung
(Gründe höhere Energiekonzentration im Futter erforderlich, Erhaltungsbedarf verteilt sich auf mehr Liter



Quelle Faktencheck: Dt. Bauernverband (2019)

Abnahme der Carbon-Footprint je Kg ECM-Milch mit zunehmender Leistung

Zusammenhang zwischen der Milchleistung und dem PCF-Milch



Ab einer Milchleistung von 5000 kg stellt sich der PCF-Milch zunehmend undifferenziert dar und ist in erster Linie abhängig von den **Standortbedingungen** und dem **Management**.

(Gerber et al. 2011)