Resilience4Dairy: Eco-efficient low cost dairy production on a mixed farm 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**

On top of this there is a bunch of other challenges farmers are faced with

f) Fluctuating product prices
g) Increased production costs (often not covered by revenue)
h) Decreasing acceptance of modern farming by the society
i) Greenhouse gas emissions
j) Climatic change (farmers have to cope with more extreme weather situations)
k) Difficulties to recruit co workers
l) Unattractive work – live - balances
m) Serious stress symptoms have been observed at many farmers
n) Difficulties to persuade the next generation to become farmers

Promising Solutions

In cooperation with farmers and advisors the R4D-project as identified a large number of solutions to help to make dairy farmers more resilient

Here some of these solutions as examples:

Mixed-farming (real or virtual)
Cooperation between complementary farms (sharing machines and workers)
Reintroduction of grazing (to reduce forage costs and increase acceptance)
Crossbreeding (for more robust cows and better marketing of excess calves)
Homegrown proteins (pulses and grass clover), self sufficiency
Multispecies swards (to increase drought tolerance and biodiversity)
Decrease input of expensive mineral N-fertilsers and concentrates
Reduced first calving age
Increased longevity of cows
Consideration of organic farming (Farm to fork strategy)

Promising Solutions

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Many of the mentioned solutions are present on several of the 120 Pilot-farms of the R4D-project

But what will it look like when all of the on the last slide mentioned solutions are applied on the same pilote farm?

How will On-Farm Eco-Efficiency and Economy of Dairy Farm in Northern Germany look like in contrast to the average farm of the region of Schleswig-Holstein when adopting these soloutions





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 with the aim 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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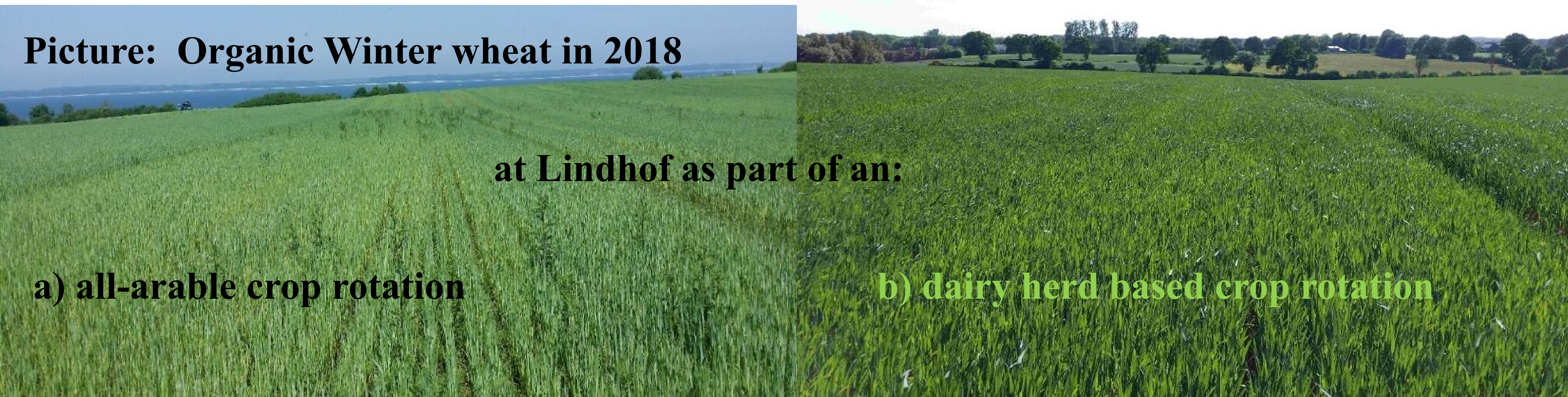
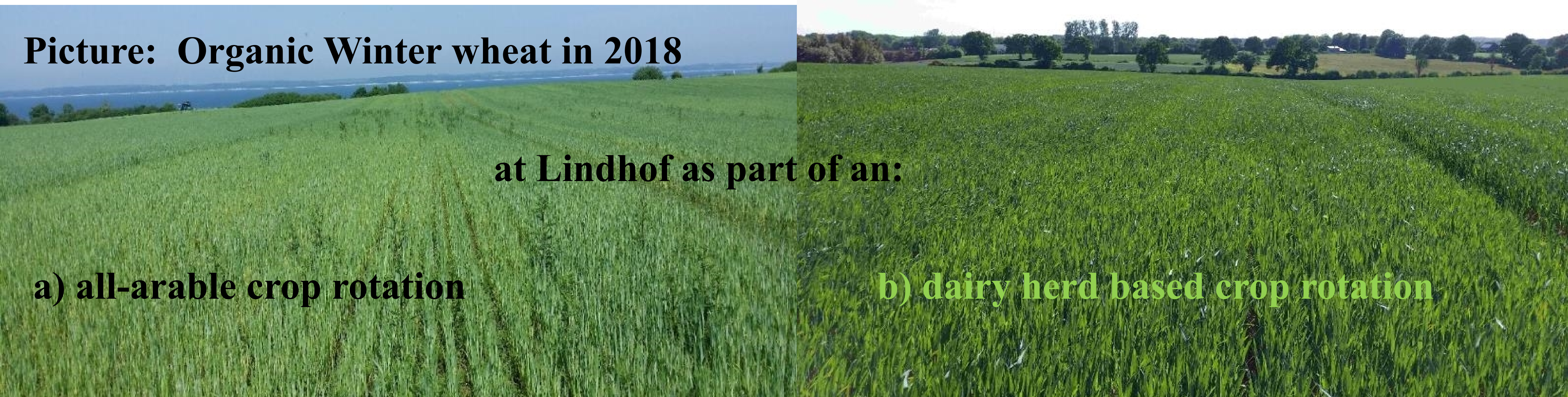


Aim of the here presented project carried out on farm level:

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



“Eco-efficient milk production” Lindhof

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Aim: Maximization of milk production from grazing at a reduced input of concentrates: 770 kg/cow/year at an actual milk yield of 7600 kg ECM/cow

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: 100 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)

Forages cooperation with an organic all-arable (swapping forage against manure)

Machine and workforce cooperation with a conventional all-arable farm

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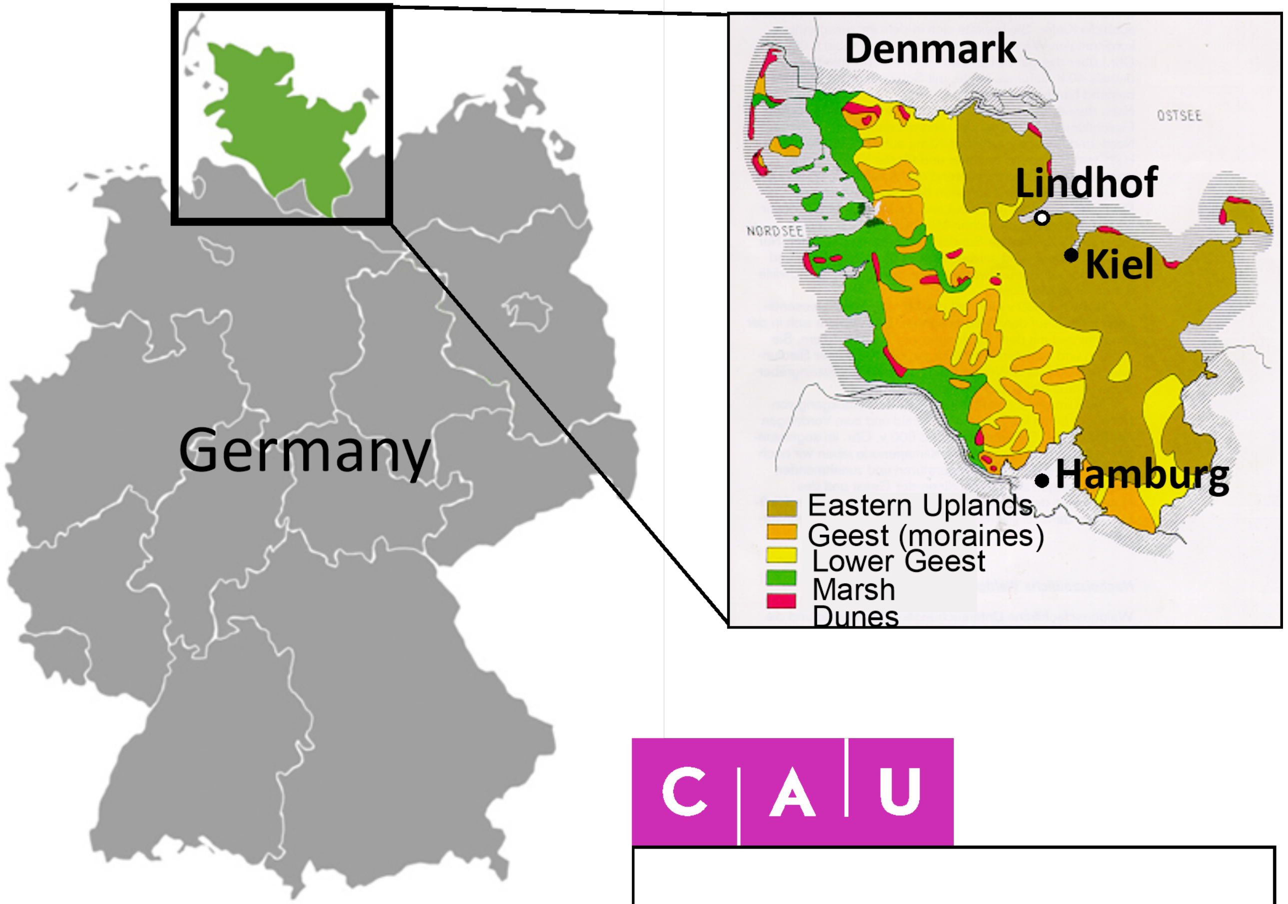
Reintroduction of grazing for dairy cows on an organic mixed farm in Northern Germany

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 (crossbreeds with Angus on nature protected permanent grassland
Precipitation: 785 mm p.a.
Temperature: average: 8.7 °C
Soil type: sandy loam, loamy sand



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Results

a) The main agronomic and environmental performance indicators at Lindhof are compared to those of the average of 356 dairy farms of the north German federal state of Schleswig-Holstein (S-H) as reported by the advisory service (BZA) *Landwirtschaftskammer S-H* (2020).

b) Measured N2O emissions and Nitrate leaching to the groundwater as well as Product Carbon Footprint (PCF) for milk production (including production of replacement heiffers) 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}

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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Results

Table 2: Full costs in the 2019/2020 financial year*

Full cost evaluation for basic feed 2019/20	**Mowed pasture Lindhof**	**BZA 2019/20 grass silage**	**BZA 2019/20 corn silage**
Energy yield, MJ NEL/ha	57,228	57,593*	84,746*
Crude Protein Yield, kg CP/ha	1, 275	1, 456	907
Total costs, €/ha	943.75	1,865.98*	2,039.44*
Total cost, ct/10 MJ NEL	16.47	32.40*	24.07*
Total cost, ct/kg CP	0.74	1.28	2.25

* Mowed pasture on the Lindhof in comparison to grass and maize silage as the most important staple feed of the 356 cattle advisory services in Schleswig-Holstein in 2019/2020; Source: LK SH 2020)

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.

(More results see last slide)

Thank you for your attention

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Fist day out on grass in early march 2022

Acknowledgements:

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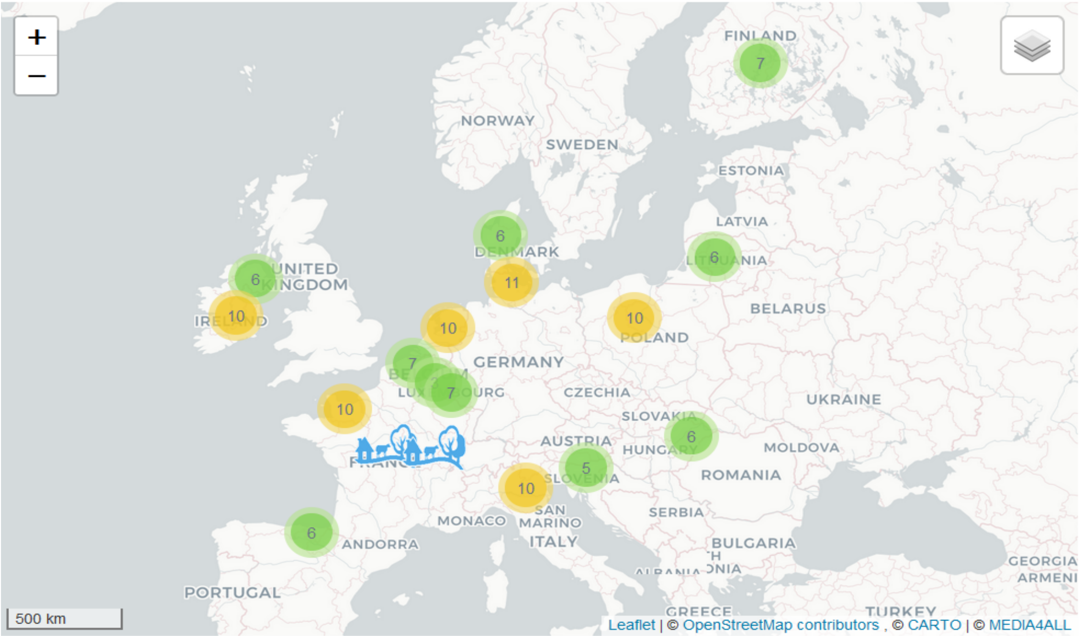
R4D: The European network for sustainable milk production

R4D is an international network funded by the EU as part of the Horizon 2020 program that aims to promote the economic, social and environmental sustainability of the dairy industry in Europe. (https://resilience4dairy.eu/)



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Additional effects of mixed farming

Before 2016, organic production at Lindhof did not proof to be resilient in the long term: no increase in SOM, cereal yields only 40% of conventional farmers

New crop rotation at Lindhof: 2-year grass clover leys followed by 3 cereal crops.
Very high pre crop effects of these grass clover leys; which also are solving weed problems with couch grass and creeping thistle
Side effect of milk production: 2500 qm slurry to fertilise the cereals
<u>increased cereal yield by 25 % is worth 22,750 € </u>=
23 ha x 1.5 t/ha Oats for oat flakes (280 €/t) + 17 ha x 1.0 t/ha Spelt (450 €/t)
+ 16 ha x 1.0 t/ha Fodder-wheat (340€/ t)

Picture: Organic Winter wheat in 2018 at Lindhof in a :

a) all-arable crop rotation

b) dairy herd based crop rotation

Results

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Material and Methods

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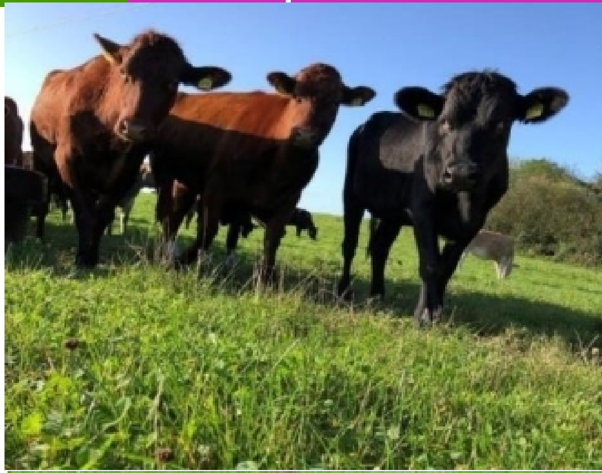
On 4 different structured dairy farms in the same area of Schleswig-Holstein:

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} $year^{-1}$

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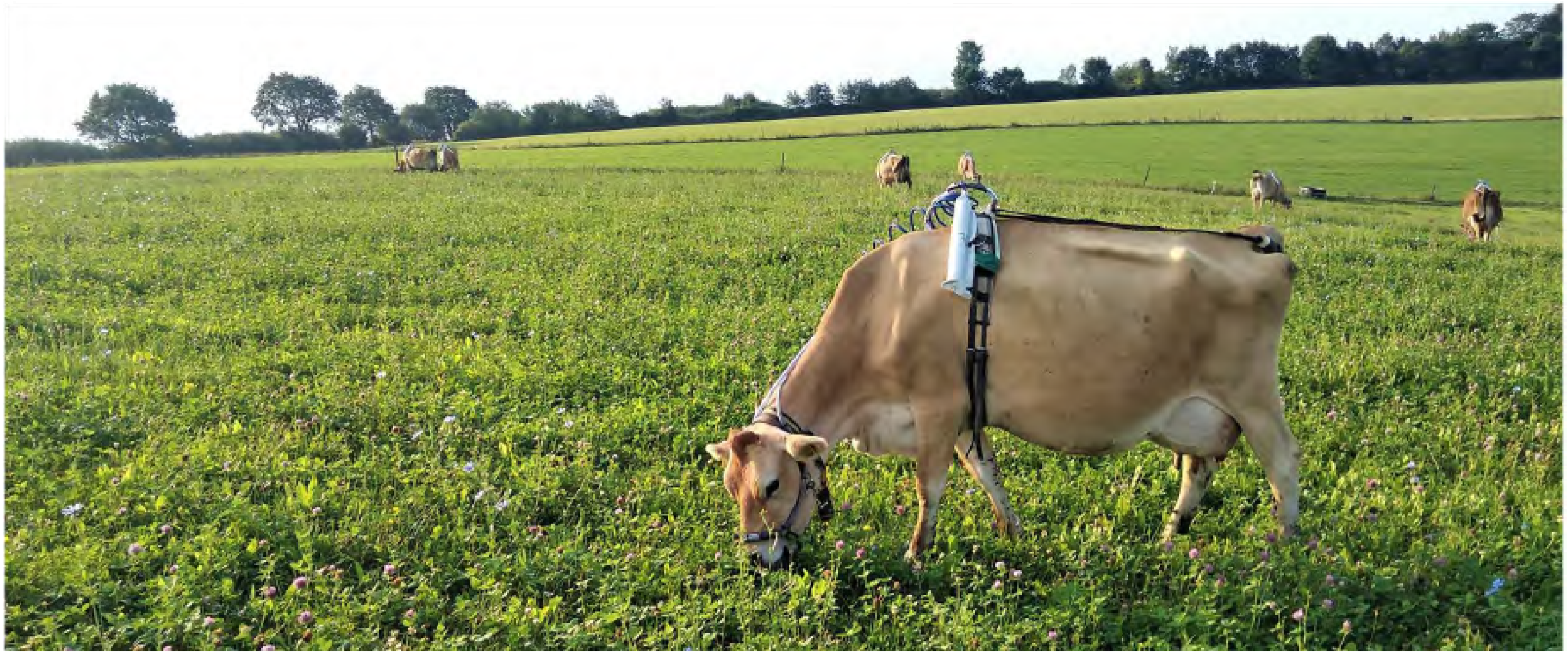
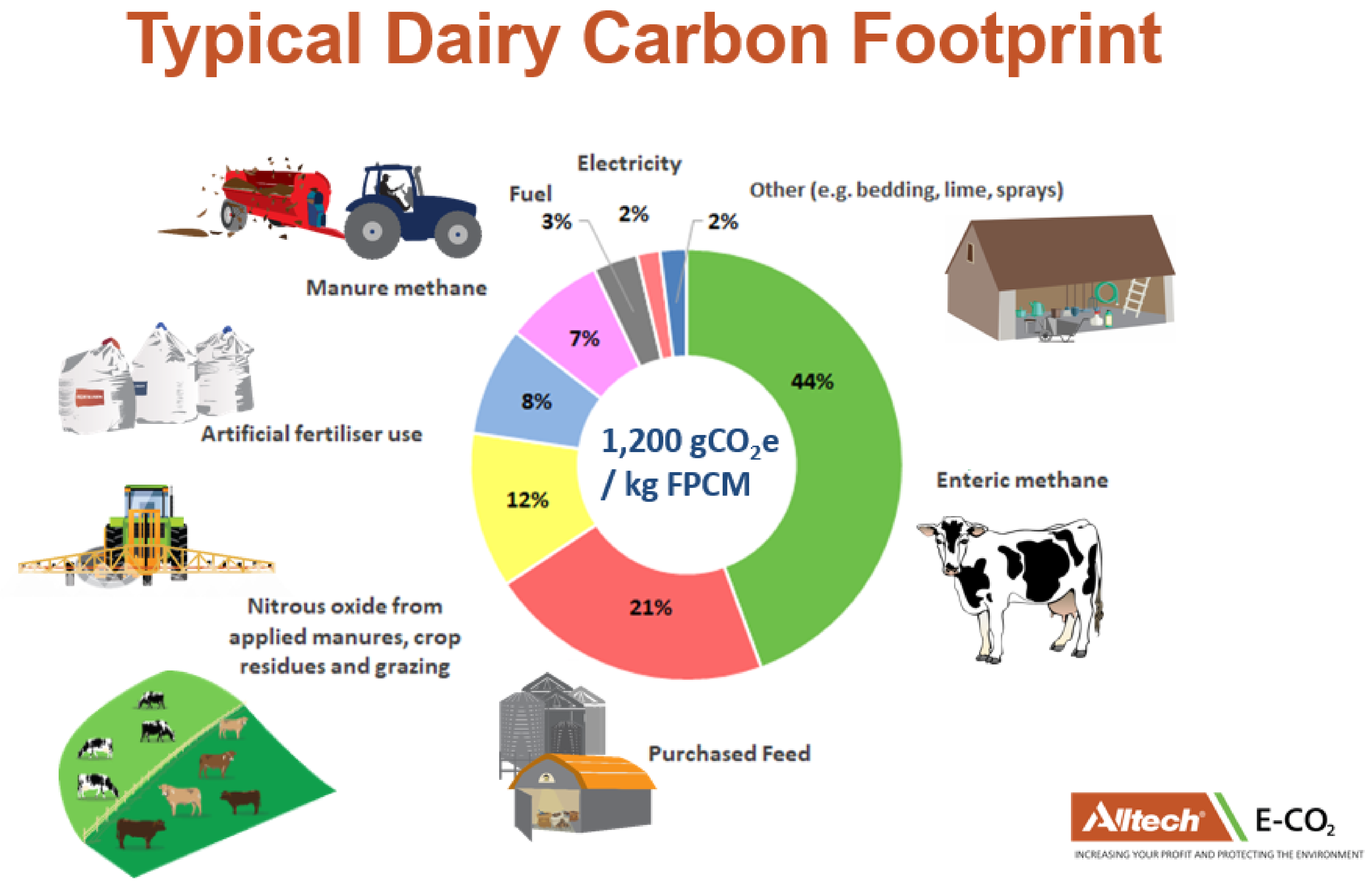
Methane Emission and Milk Production From Jersey Cows Grazing Perennial Ryegrass–White Clover and Multispecies Forage Mixtures

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



GreenHouseGas –Emissions in CO_2-equivalents per kg Energy-corrected Milk based on an assesment of over 9000 farms in Europe (Alltech 2019)



Introduction: Why being interested in mixed farming?

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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.

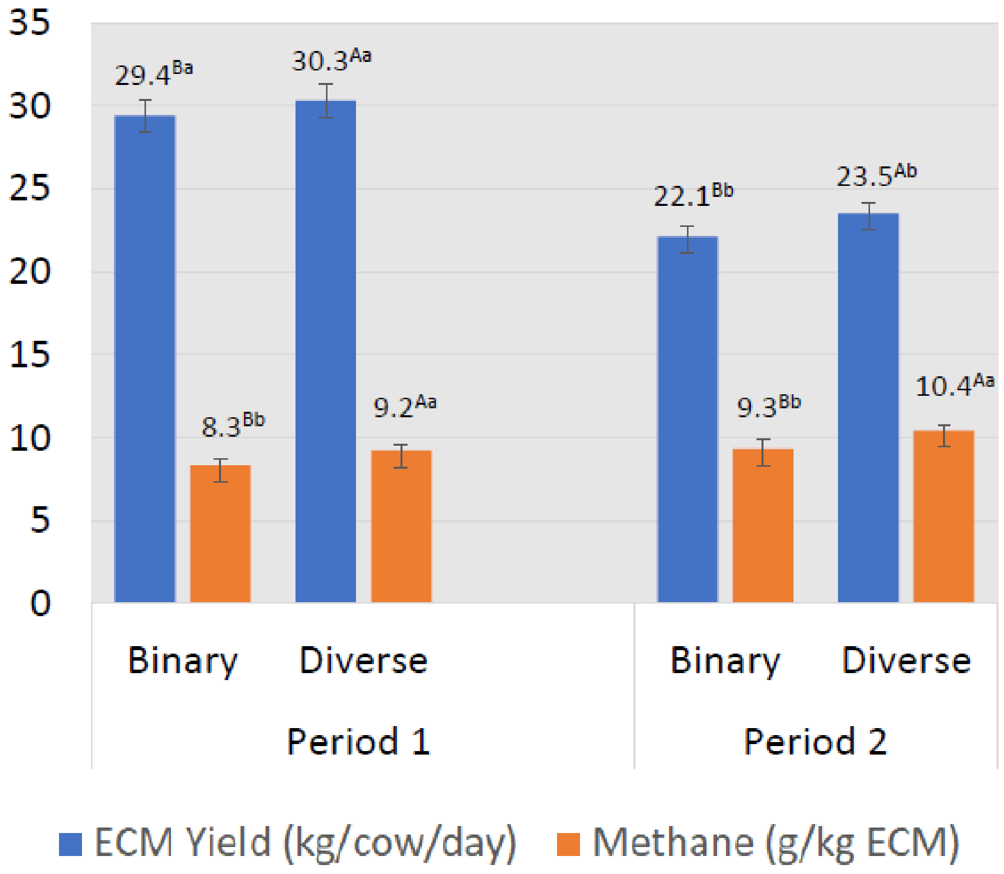
Pasture is considered a cheap and environmentally friendly forage source (Dillon et al. 2008, Rotz et al. 2009)

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)

In vivo experiment: Main results

Milk Yield (ECM) and methane intensity ($g\ CH_4/kg\ ECM$)



Forage quality (NEL, MJ/kg DM; OM Dig., %) and dry matter intake (DMI, kg DM/cow day)

	P1 (2-18 May 2019)		P2 (15-30 August 2019)	
	Binary	Diverse	Binary	Diverse
NEL	7.7 (0.0) ^{Aa}	7.5 (0.0) ^{Ba}	6.9 (0.1) ^{Ab}	6.7 (0.0) ^{Bb}
OM Dig.	87.6 (0.2)^{Aa}	84.4 (0.2)^{Ba}	80.2 (0.4)^{Ab}	77.9 (0.4)^{Bb}
DMI *	13	15	11	13

*Estimated with pre- and post-grazing measurements of the herbage mass in addition to 2 kg of concentrate.

- ❑ **Cows grazing Diverse mixtures can produce very high milk yields with very low methane emissions.**

^{A,B} Differences between treatment, ^{a,b} differences between the periods, according to the adjusted p-value method.

Performance of pasture-based system in the world

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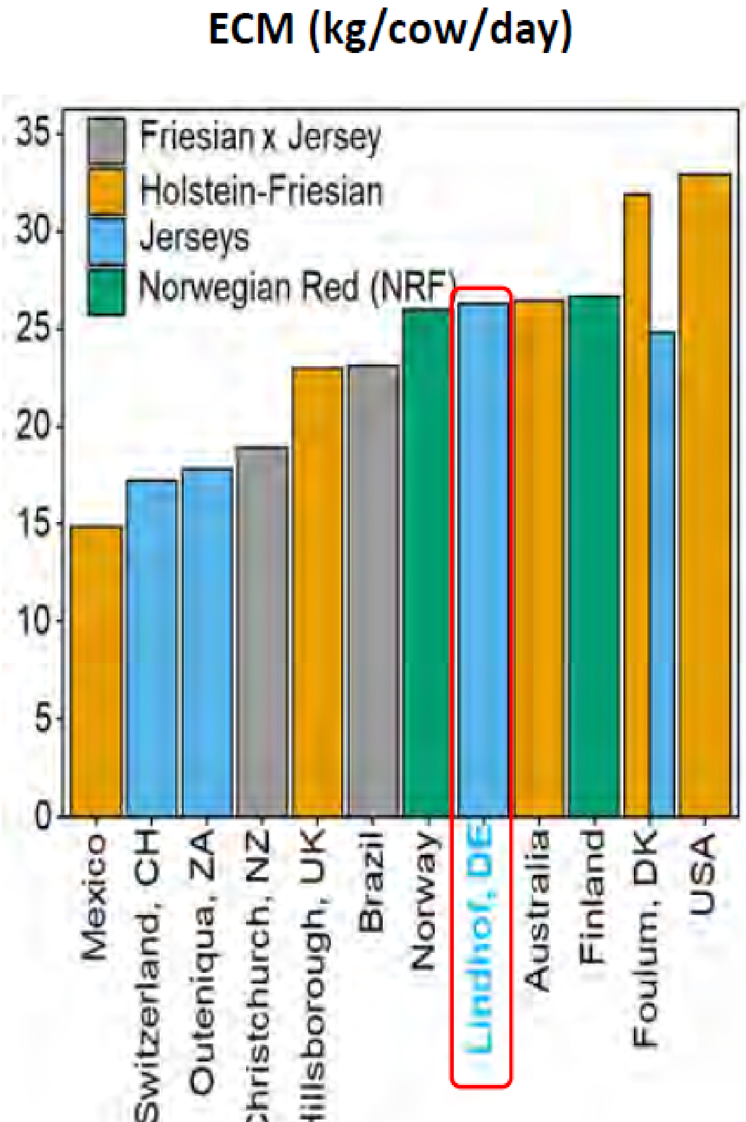
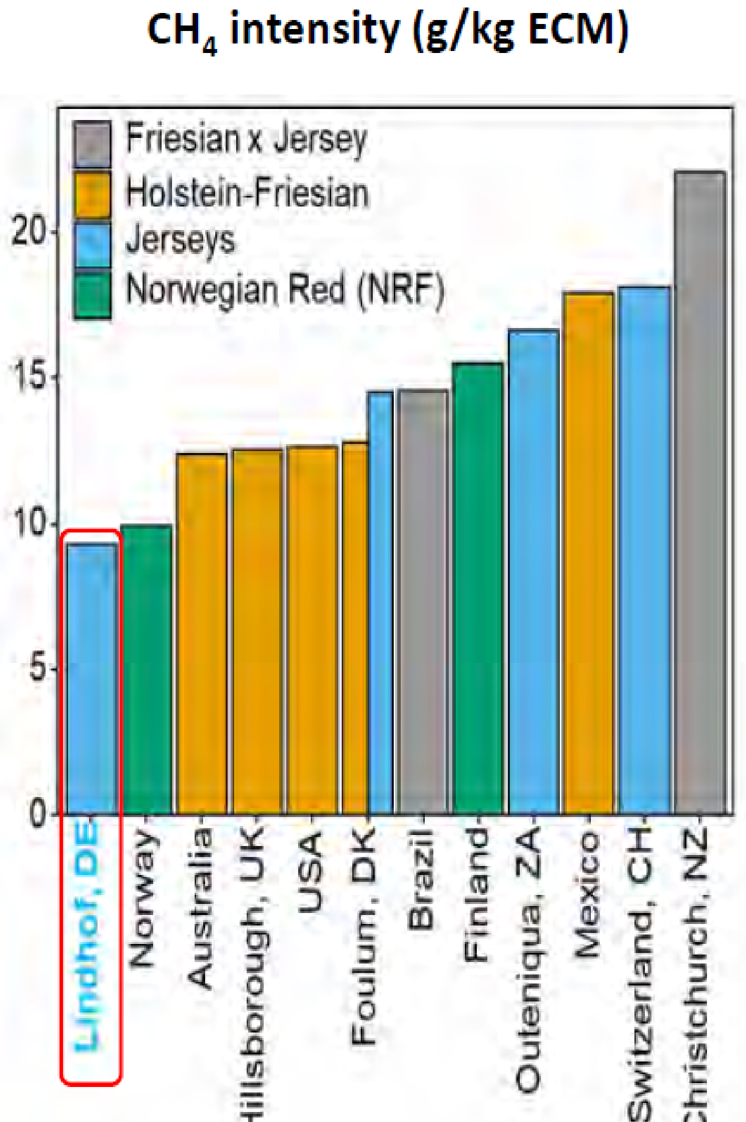
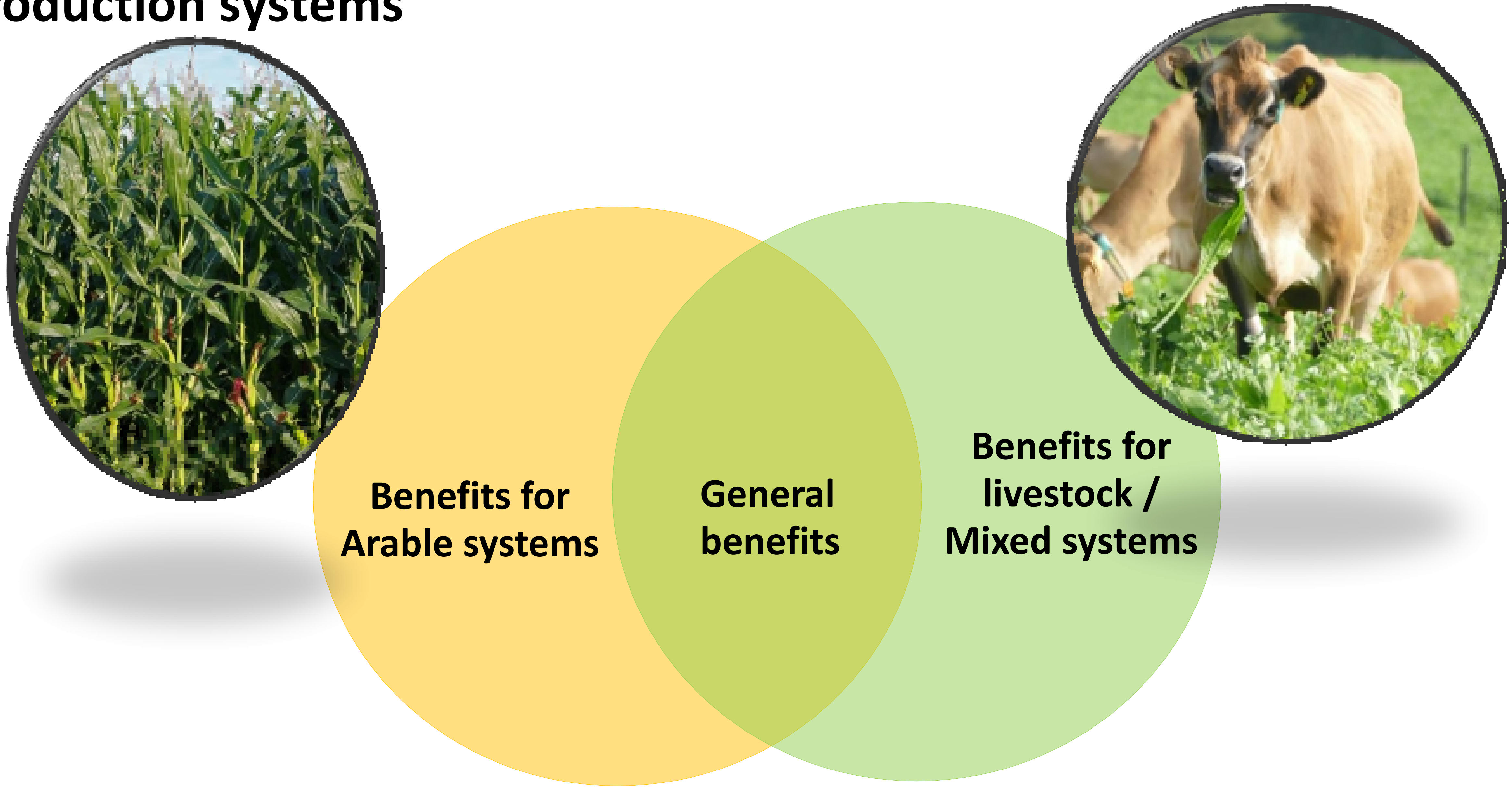


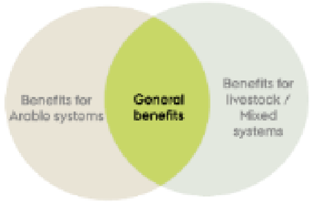


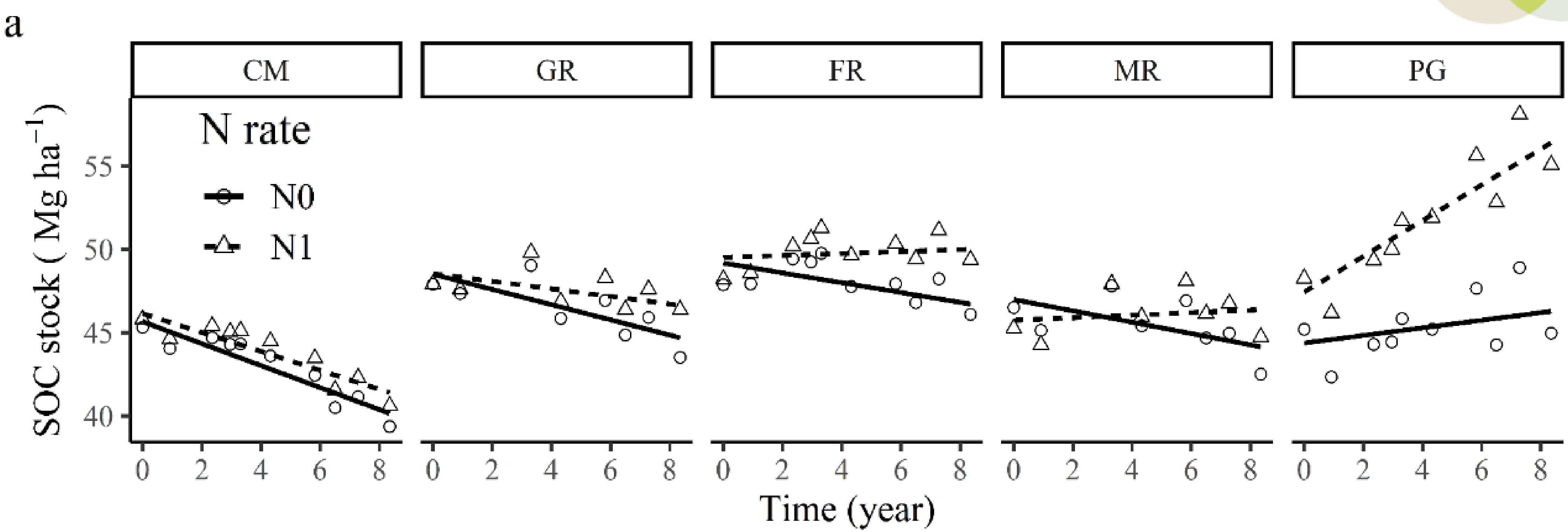
- Lindhof system(ICLS) shows high performance and low environmental impact when compared with other pasture-based systems.

(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)

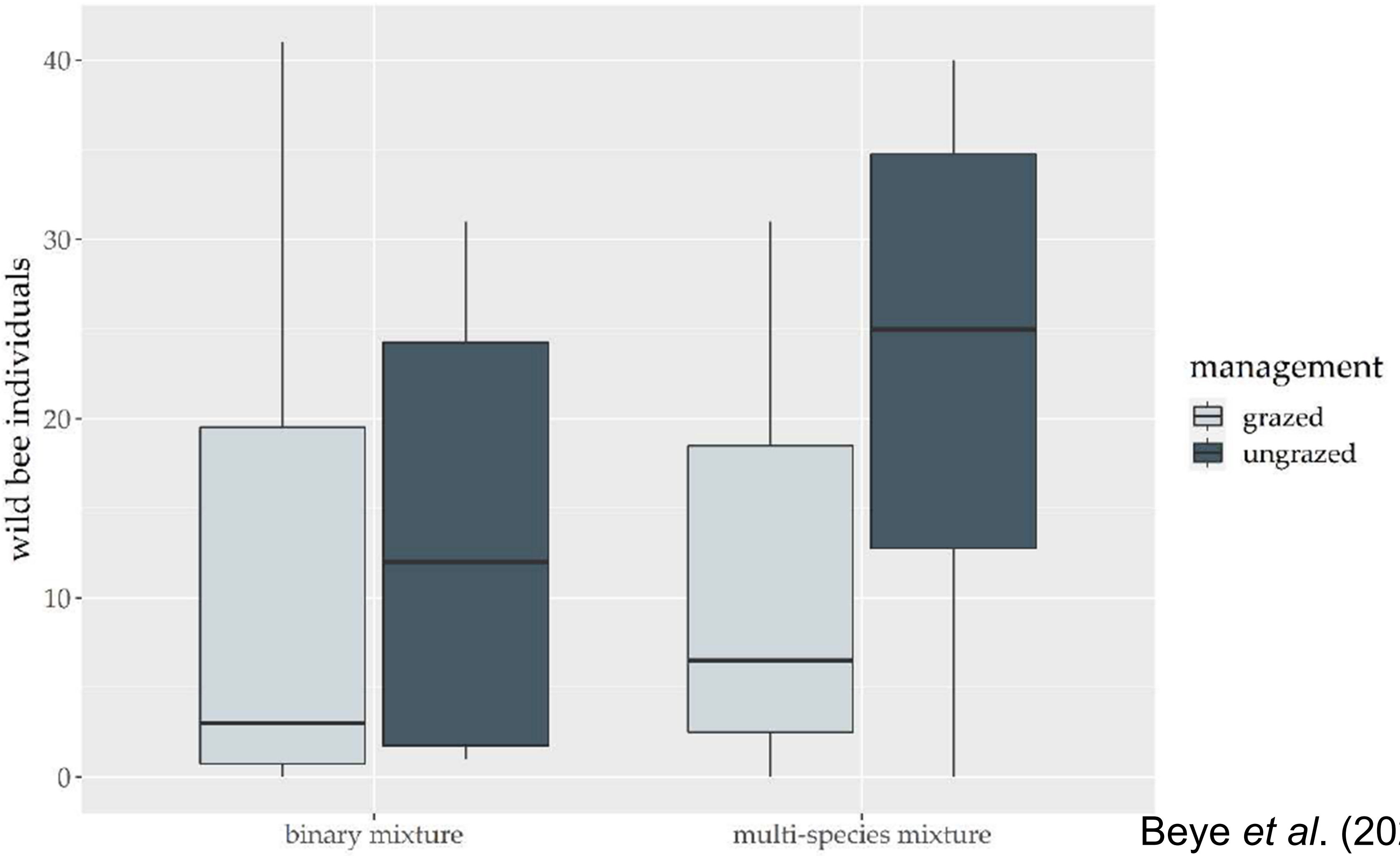
PG: Permanent grassland

N0: unfertilized

N1: 240 kg N to non-legumes

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

Especially grazed multispecies mixtures had high pollinator abundance



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

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

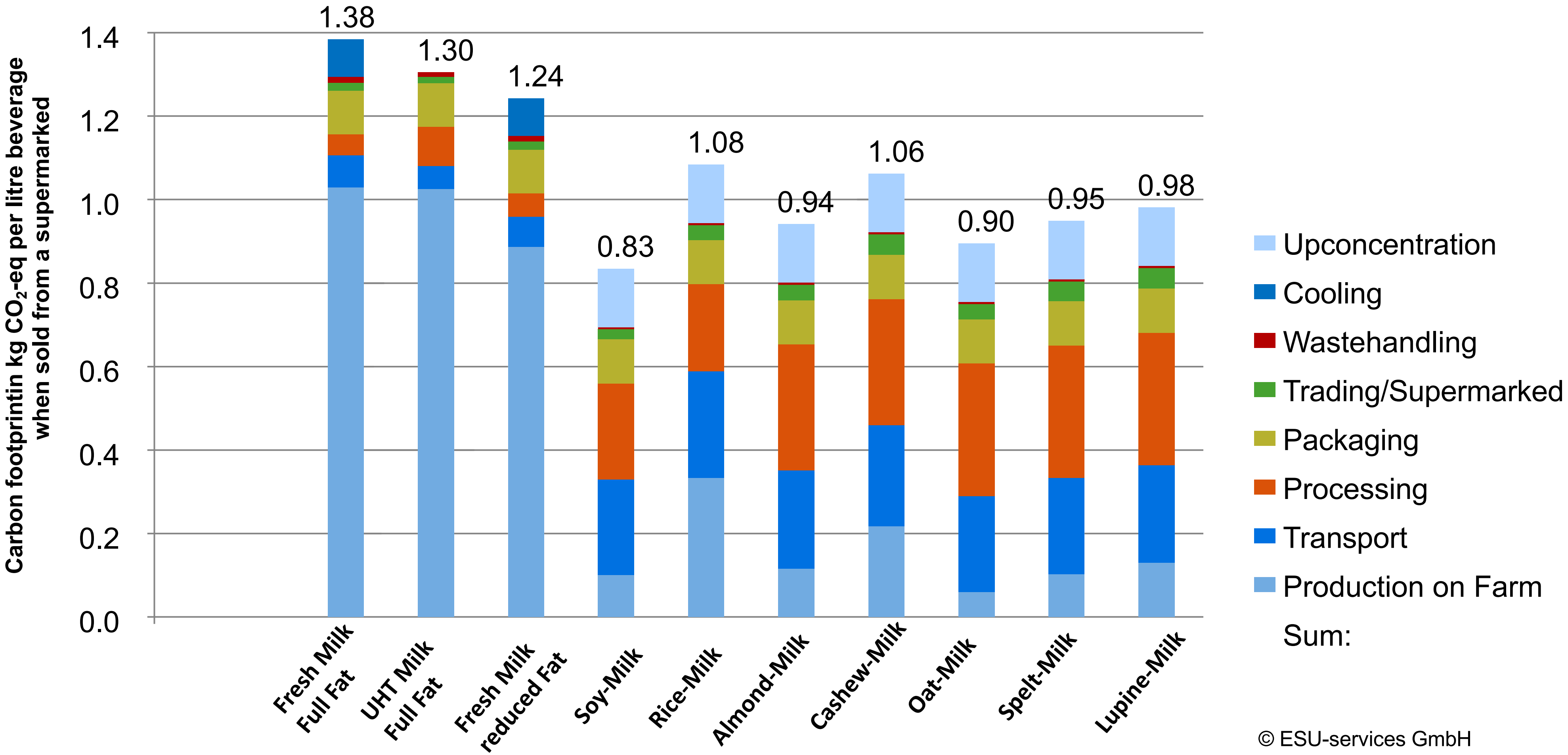


Fig. 5.6 Comparison of the various milk drinks and fortified drinks for the greenhouse effect (kg CO2-eq per liter ex supermarket, IPCC 100a, including additional influences from air transport

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/

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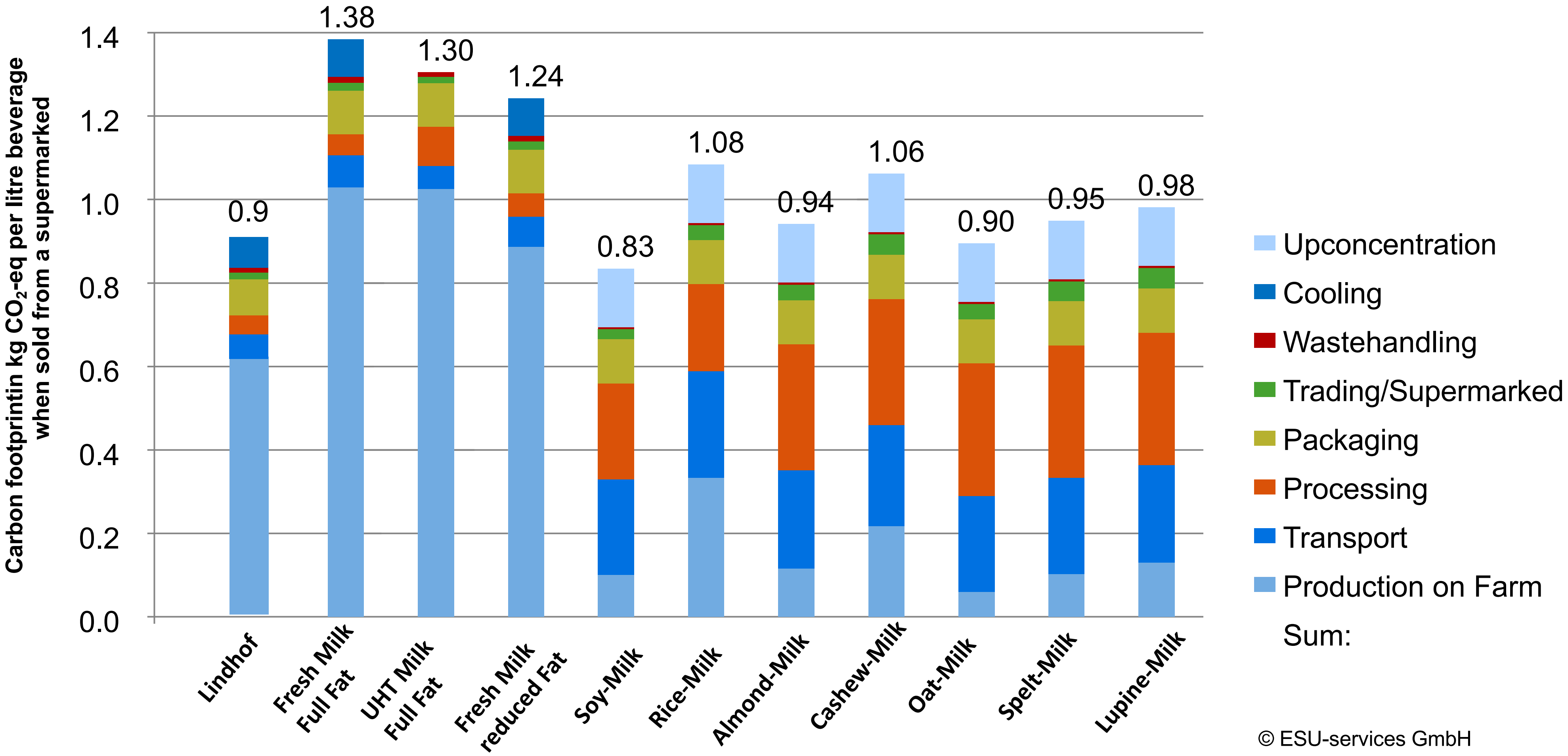

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Aim of the here presendet project carried out on farm level:

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?

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C A U

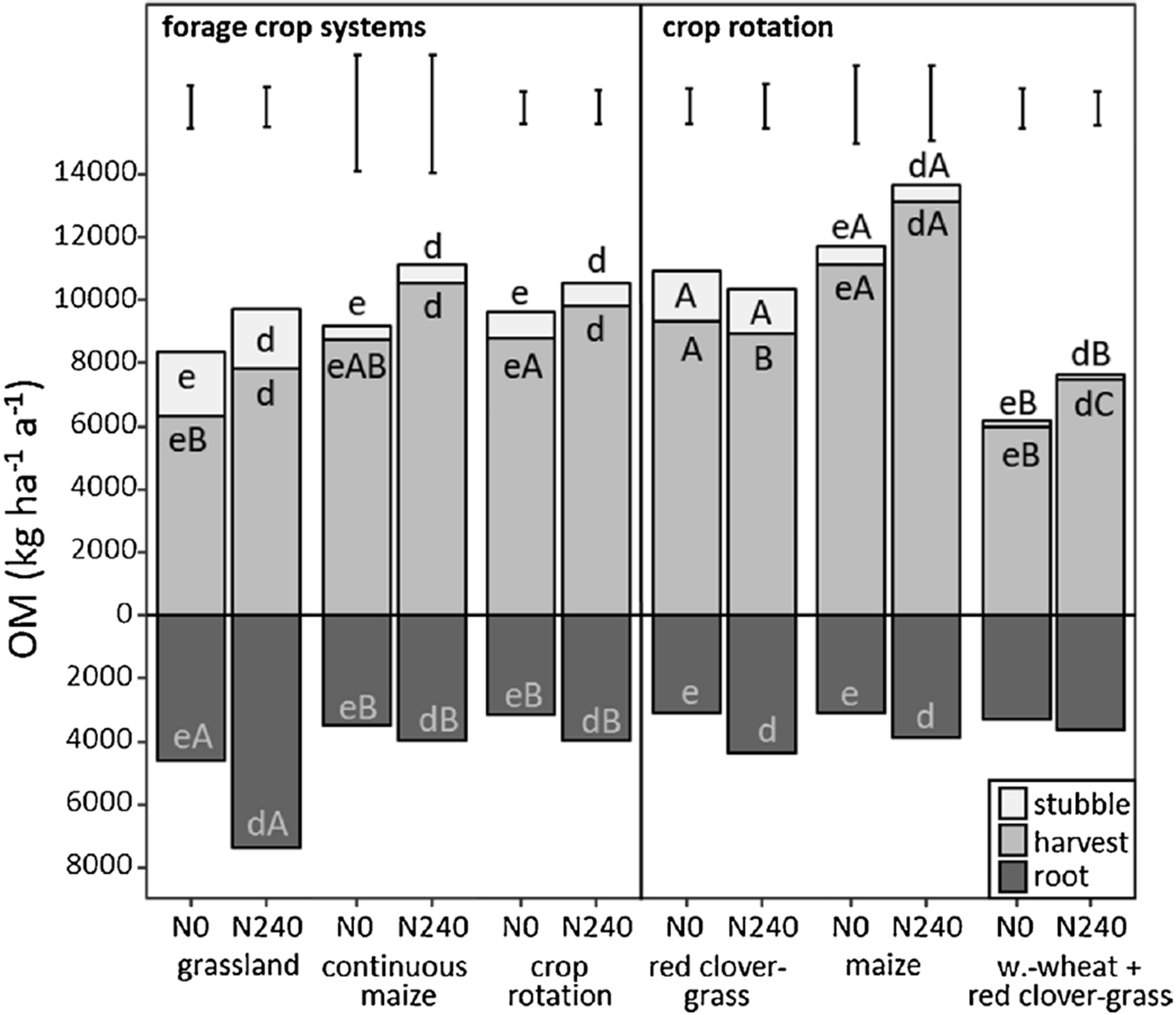
Can the reintroduction of a dairy herd on a former specialized all arable farm reduce theses challenges and produce milk profitably in a climatic friendly way.

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

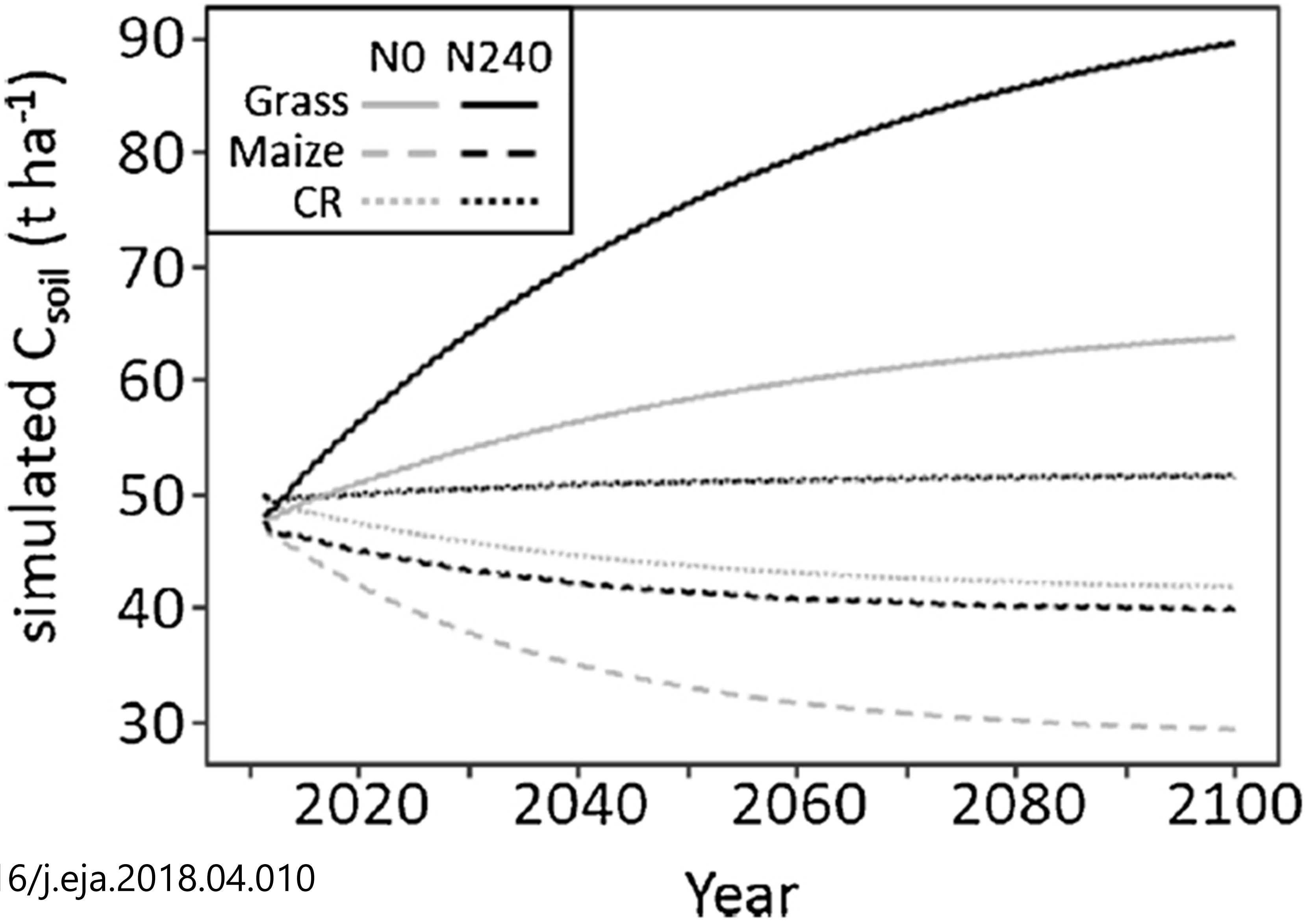
Reinsch T, Loza C, Malisch CS, Vogeler I, Kluß C, **Loges R**, Taube F 2021. **Toward Specialized or Integrated Systems in Northwest Europe: On-Farm Eco-Efficiency of Dairy Farming in Germany.** Front. Sustain. Food Syst. 5, 614348. https://doi.org/10/gj68j4

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

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

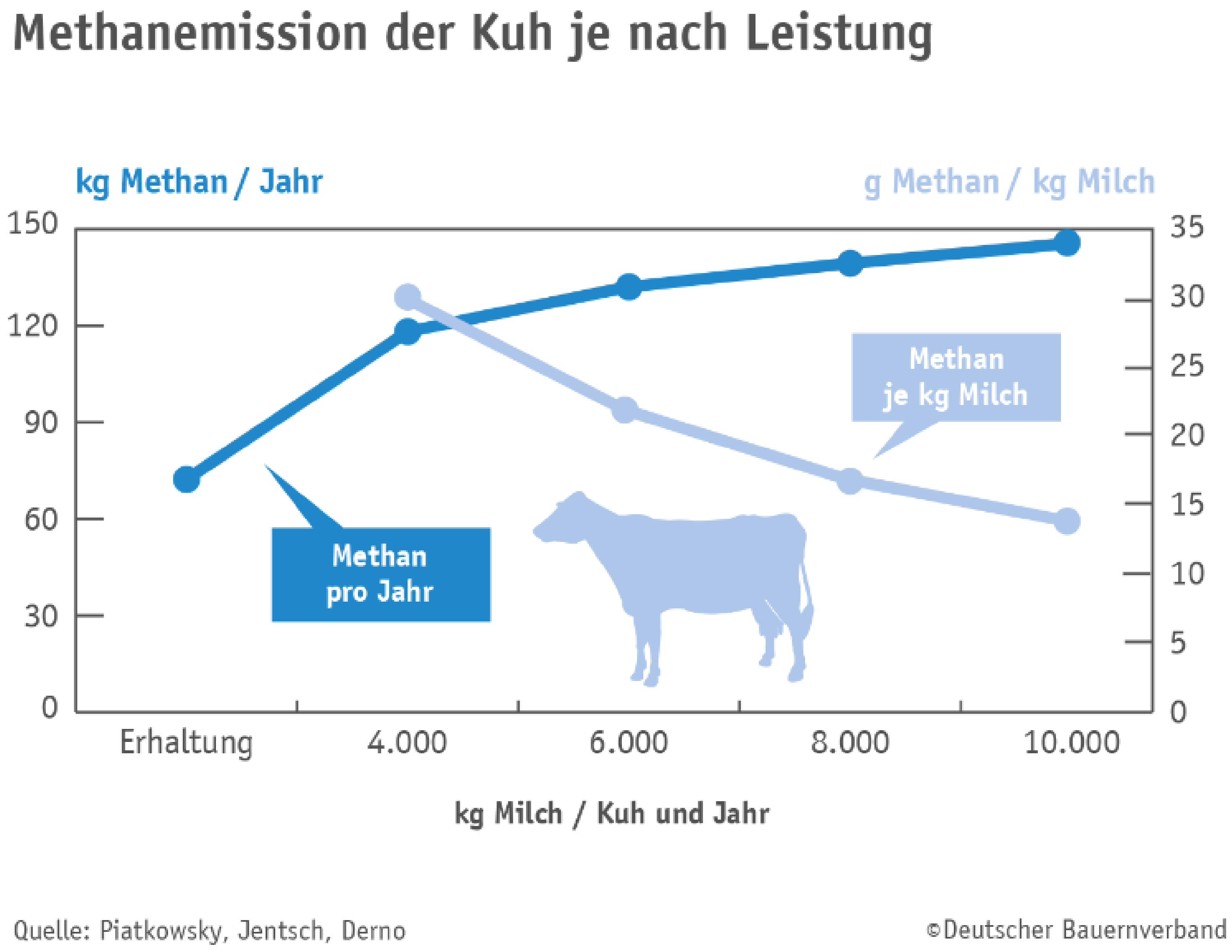


Loges et al, 2018: 10.1016/j.eja.2018.04.010



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

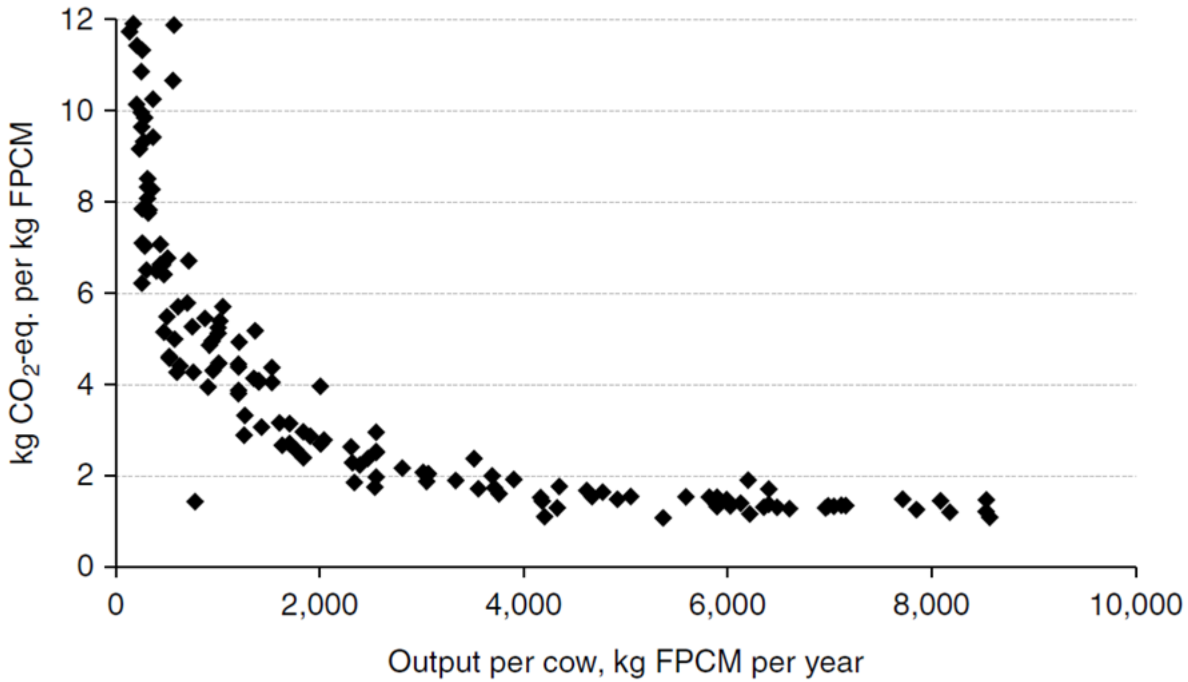
Abnahme der Methanemission je Kg ECM-Milch mit zunehmender Leistung
(Gründe höhere Energiekonzentration im Futter erforderlich, Erhaltungsbedarf verteilt sich auf mehr Liter



Quelle Faktencheck: Dt. Bauernverband (2019)

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

Zusammenhang zwischen der Milchleistung und dem PCF-Milch



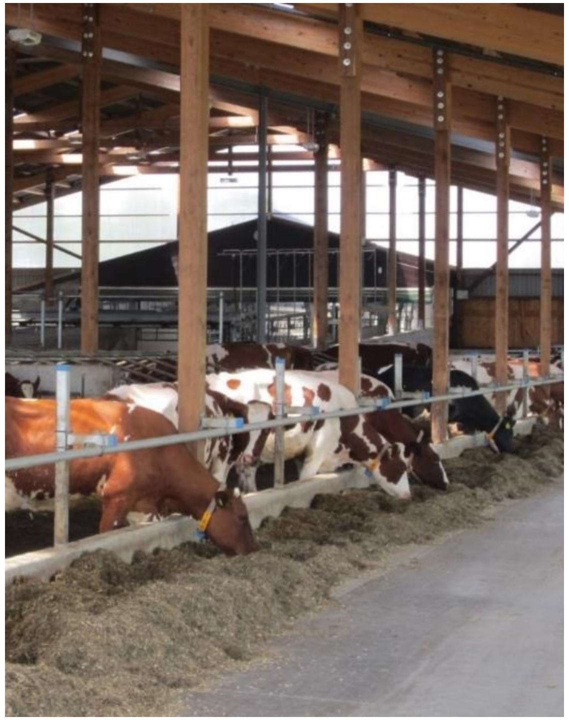
Ab einer Milchleistung von 5000 kg stellt sich der PCF-Milch zunehmend undifferenziert dar und ist in erster Linie abhängig von den **Standortbedingungen** und dem **Management**.

(Gerber et al. 2011)

Product-Carbon-Footprint Milch Meta-Studie auf Basis der international verfügbaren wissenschaftlichen Literatur zum Thema

C | A | U
Christian-Albrechts-Universität zu Kiel
Grünland und Futterbau/
Ökologischer Landbau

Klimarelevanz der Milchproduktion Produkt Carbon Footprint Milch in Abhängigkeit des Haltungssystems



Stallhaltung (ganzjährig)
(kein Zugriff auf Weide)

Intermediär
(<50% der TM-Aufnahme von Weide; >25% Kraftfutter)

Weidehaltung
(>50% der TM-Aufnahme von Weide; max. 25% Kraftfutter)

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

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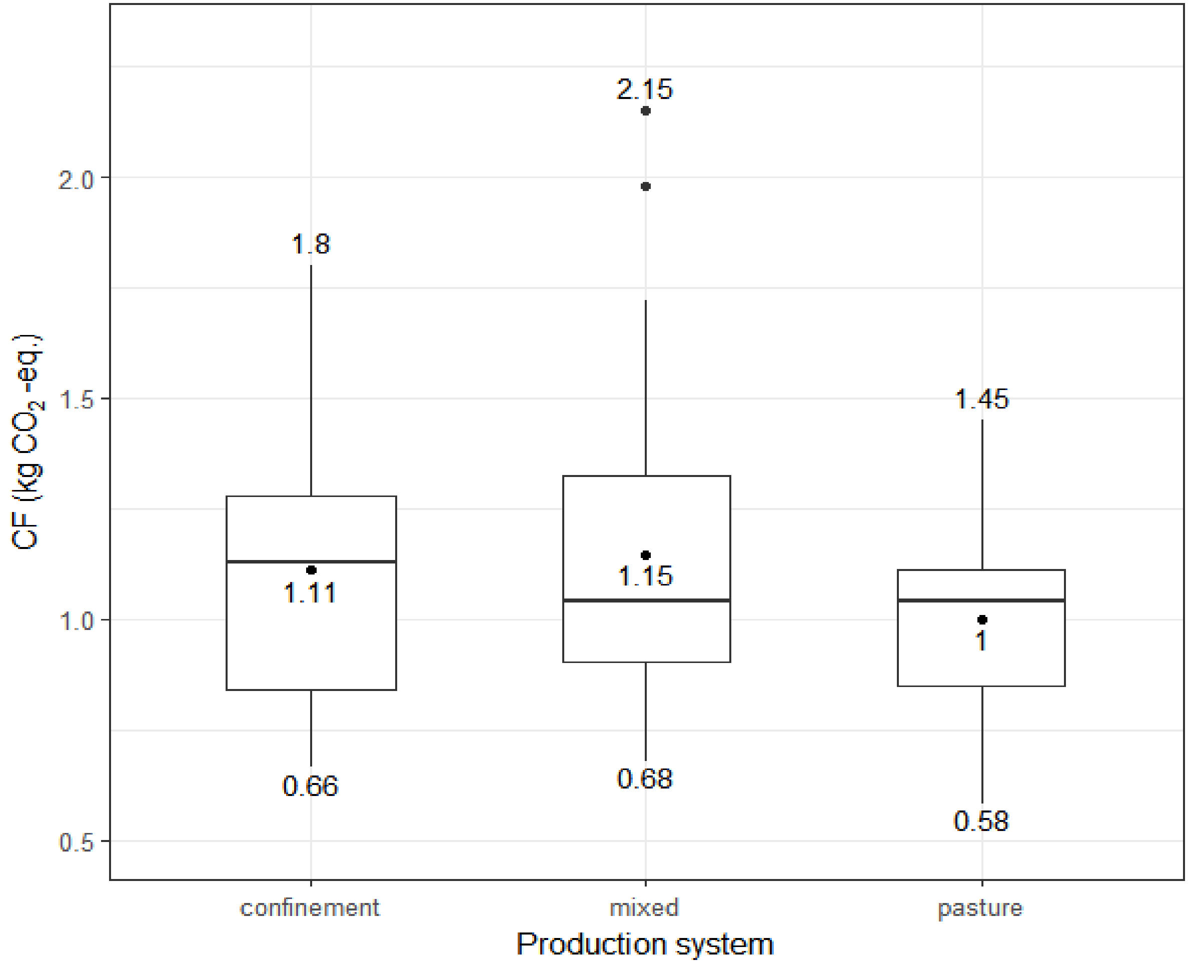

Basiert auf über 100 wissenschaftlich redigierte Publikationen!!!!

Ganzjährige Stallhaltung (kein Zugriff auf Weide)	**Intermediär** (<50% der TM-Aufnahme von Weide; >25% Kraftfutter)	**Weidehaltung** (>50% der TM-Aufnahme von Weide; max. 25% Kraftfutter)

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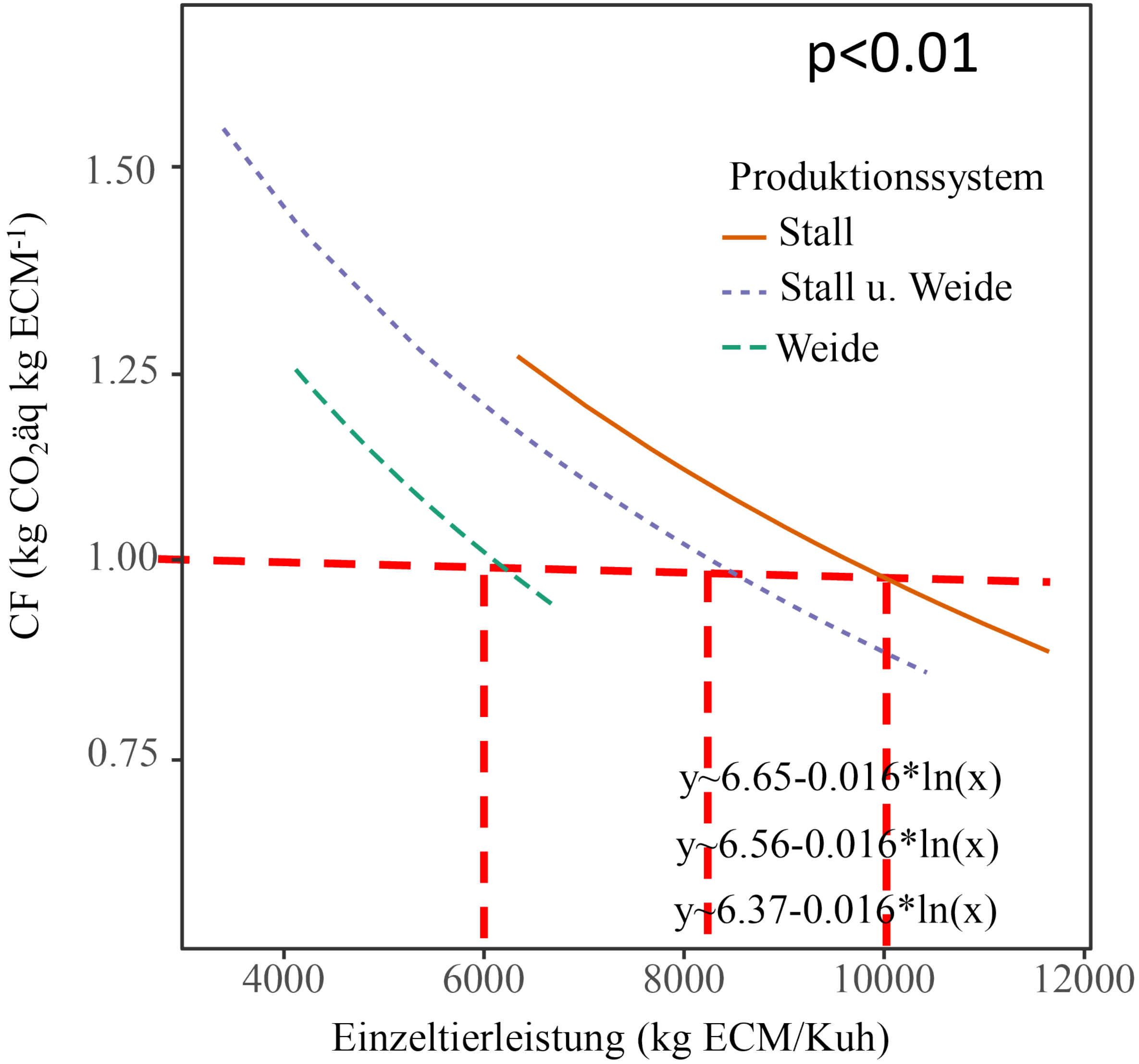
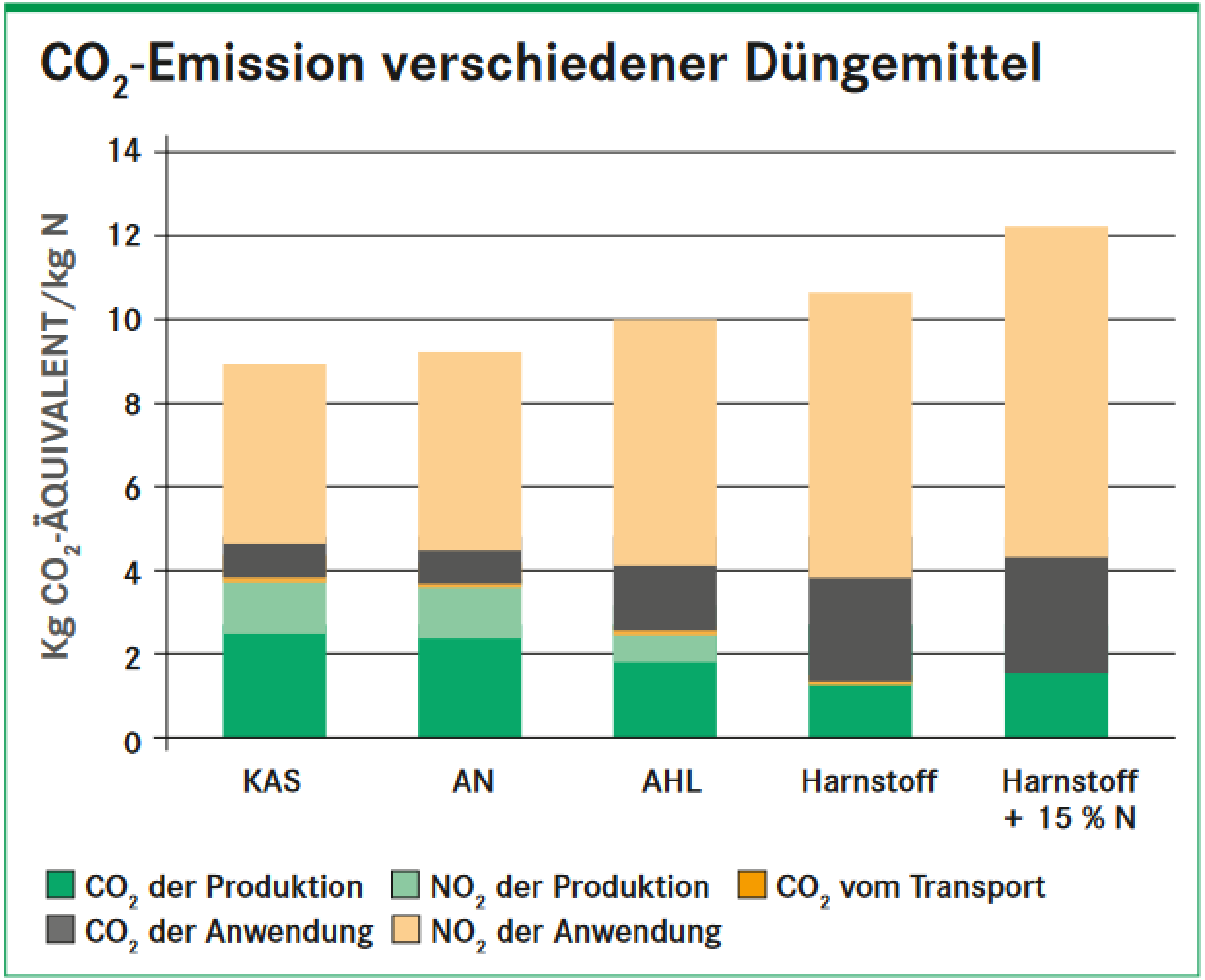


Der Herdendurchschnittsleistung kommt eine große Bedeutung bei der Klimarelevanzberechnung im jeweiligen Haltungssystem zu

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

Weide hilft Mineral-N-sparen

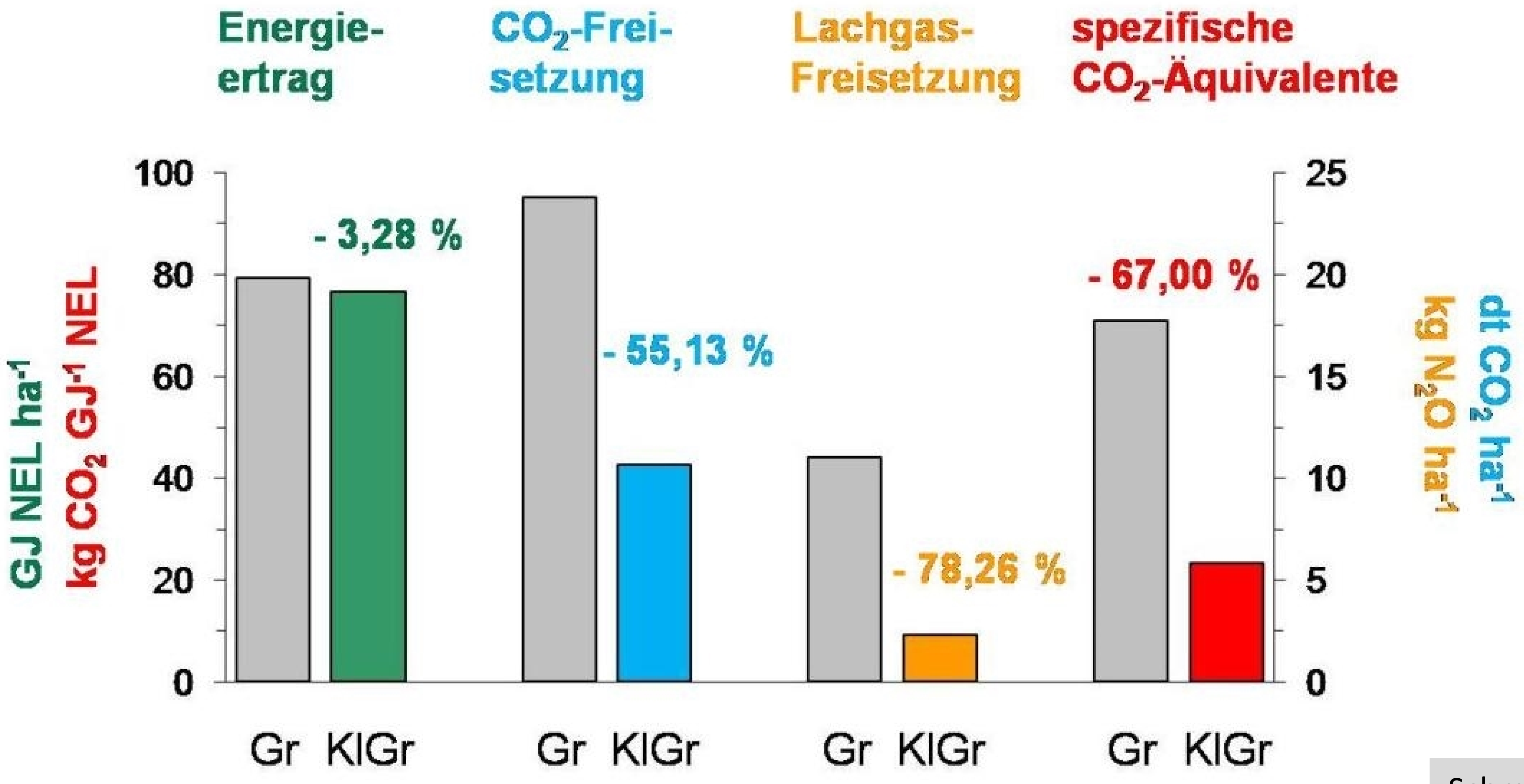


Heinzelmeier 2018

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

(WD des Bundestages 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/

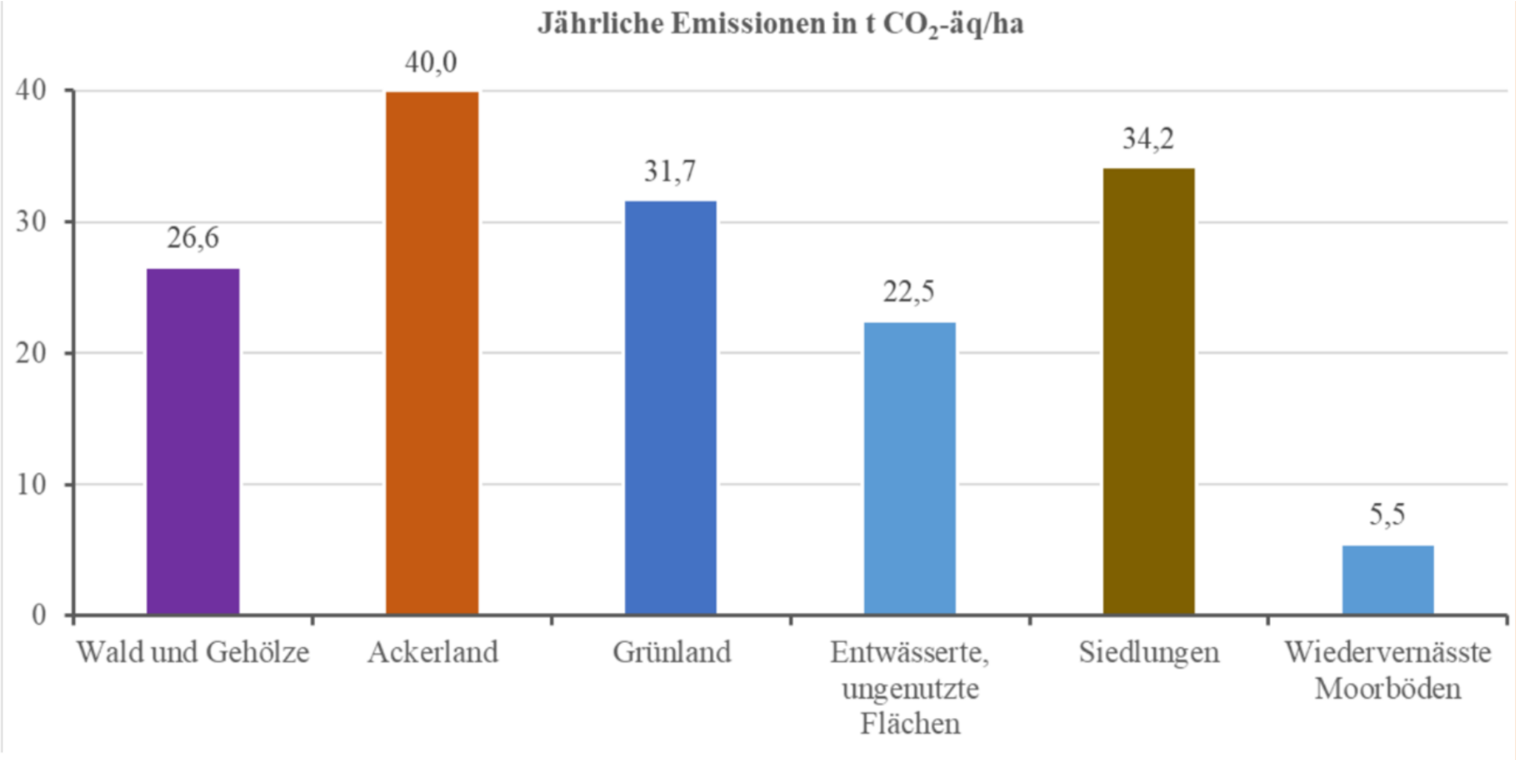
Carbon Footprint der Rindermast in Schleswig-Holstein (kg CO_2äq/kg SG), Reinsch et al 2019.

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

Aber:

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)