Specialized or Integrated Systems:
On-Farm Eco-Efficiency of Dairy Farming in Northern Germany

Ralf Loges, Christof Kluß, Iris Vogeler, Thorsten Reinsch and Friedhelm Taube

Grass and Forage Science/Organic Agriculture, University of Kiel, 24118 Kiel, Germany

rloges@email.uni-kiel.de





Introduction: Challenges of spezialized farming

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 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?

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.

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)

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

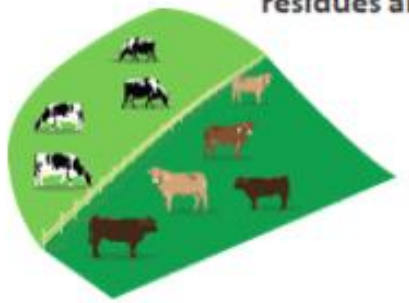
C | A | U

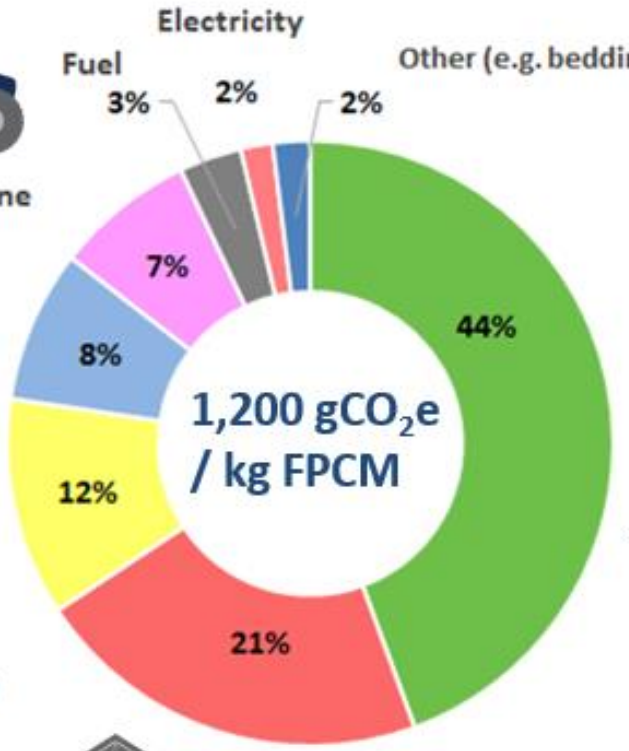
Typical Dairy Carbon Footprint

Manure methane

Artificial fertiliser use

Nitrous oxide from applied manures, crop residues and grazing





Enteric methane

Purchased Feed

Alltech E-CO$_2$

INCREASING YOUR PROFIT AND PROTECTING THE ENVIRONMENT

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).

The share of grass clover in the crop rotation was increased from 20% to 40%

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).

The share of grass clover in the crop rotation was increased from 20% to 40%

Picture: Organic Winter wheat in 2018

at Lindhof as part of an:

a) all-arable crop rotation

b) dairy herd based crop rotation

“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: 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)

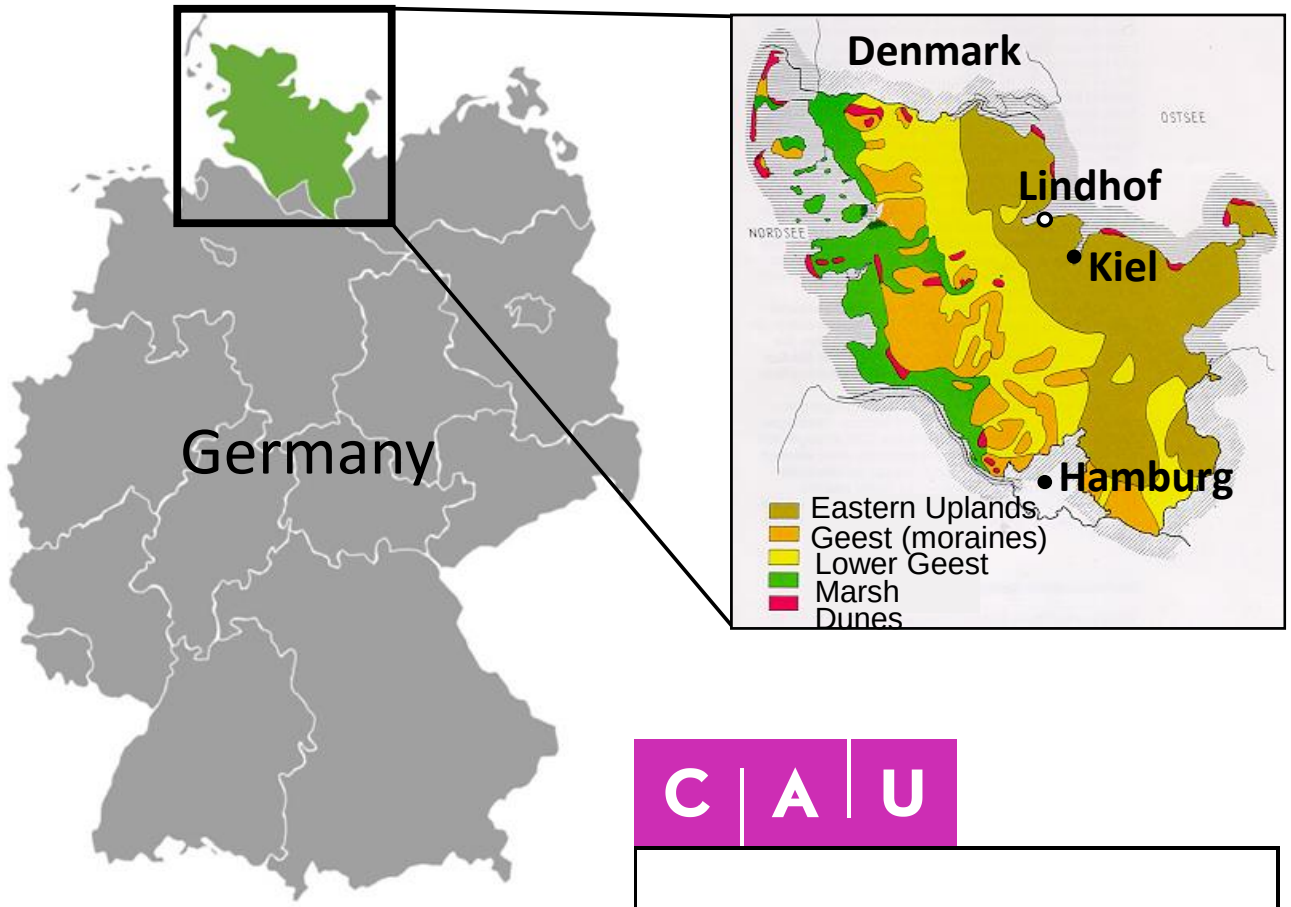
Selfsufficiant with concentrates (Triticale + Faba beans)

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**



Christian-Albrechts-Universität zu Kiel
Faculty of Agricultural and Nutritional Sciences

Material and Methods

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)

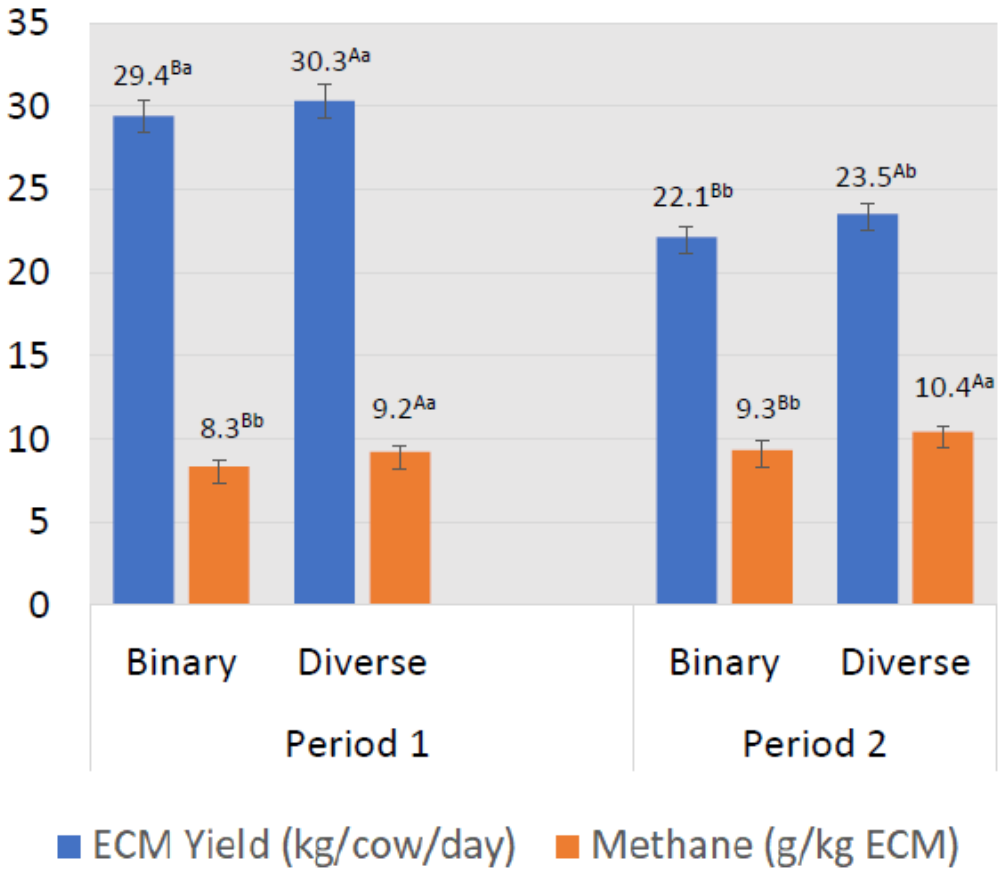
Methane Emission and Milk Production From Jersey Cows Grazing Perennial Ryegrass–White Clover and Multispecies Forage Mixtures

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

In vivo experiment: Main results

Christian-Albrechts-Universität zu Kiel

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.

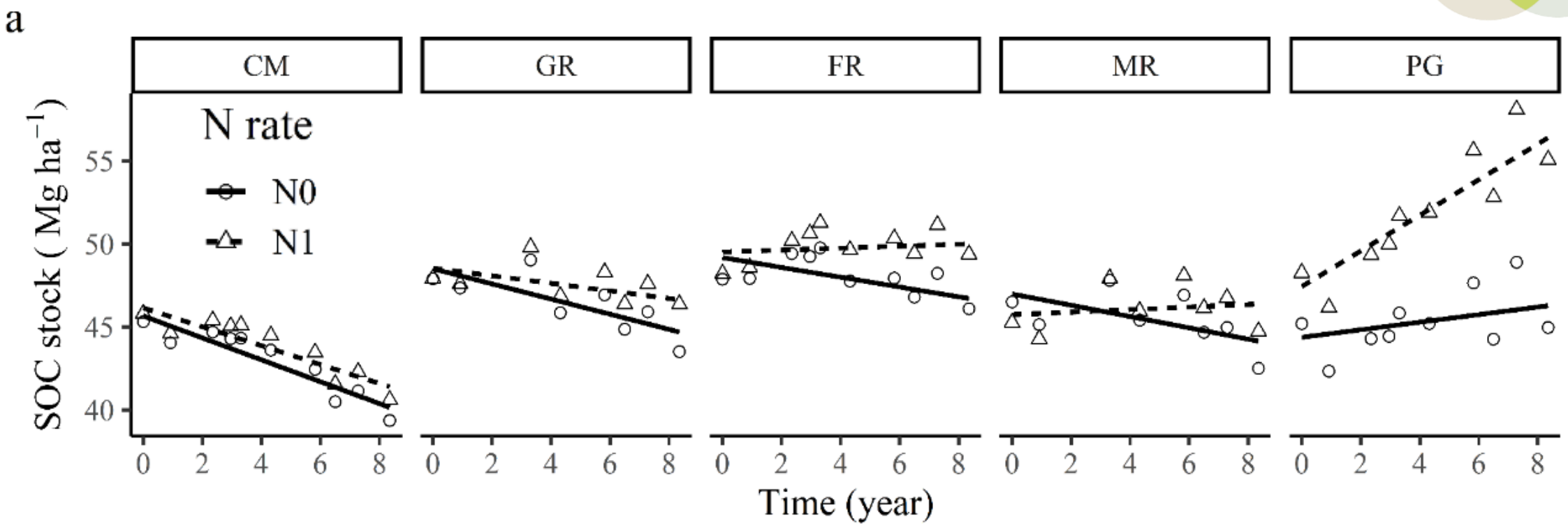
(Diverse) temporary Grasslands can provide benefits independent of production systems

Benefits for Arable systems

General benefits

Benefits for livestock / Mixed 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)

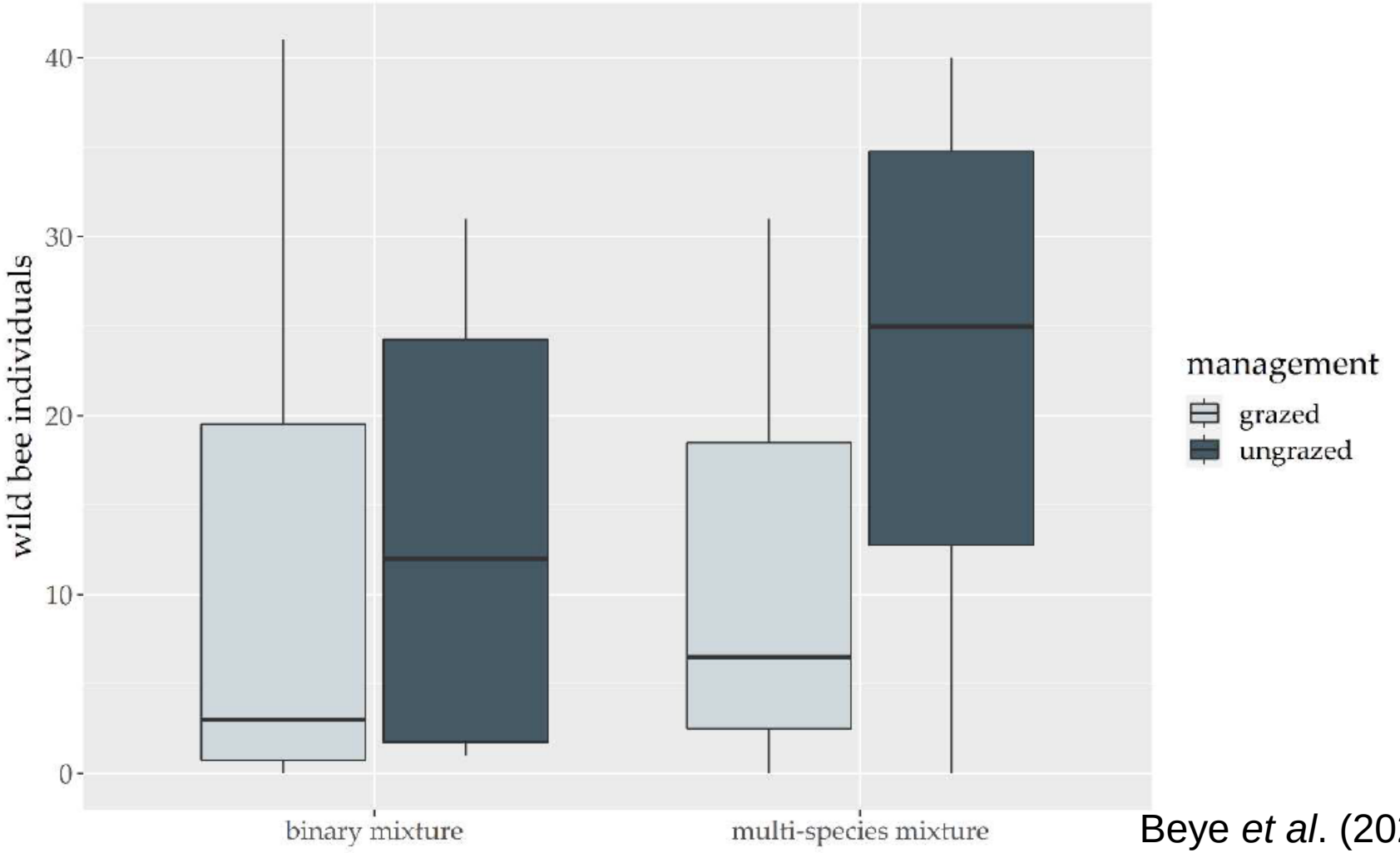
PG: Permanent grassland

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

Conclusions and additional results

Conclusion

High milk yields per area fodder production at **almost no nitrate losses and a very low product carbon footprint for milk** show **the capability of a rotational ley grazing systems to reduce 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.

additional results

*Economy: On **top*** **the presented system produces milk at 28% lower fodder costs compared to the average of almost 1000 dairy farms of the north German federal state of Schleswig-Holstein a**s reported by the advisory service Landwirtschaftskammer S-H (2020).

(This and other results are presented **in R4D-Session 71 on Thursday at 10.45**: Ralf Loges: Eco-efficient low-cost pasture based dairy production on a mixed farm in Northern Germany

Thank you for your attention

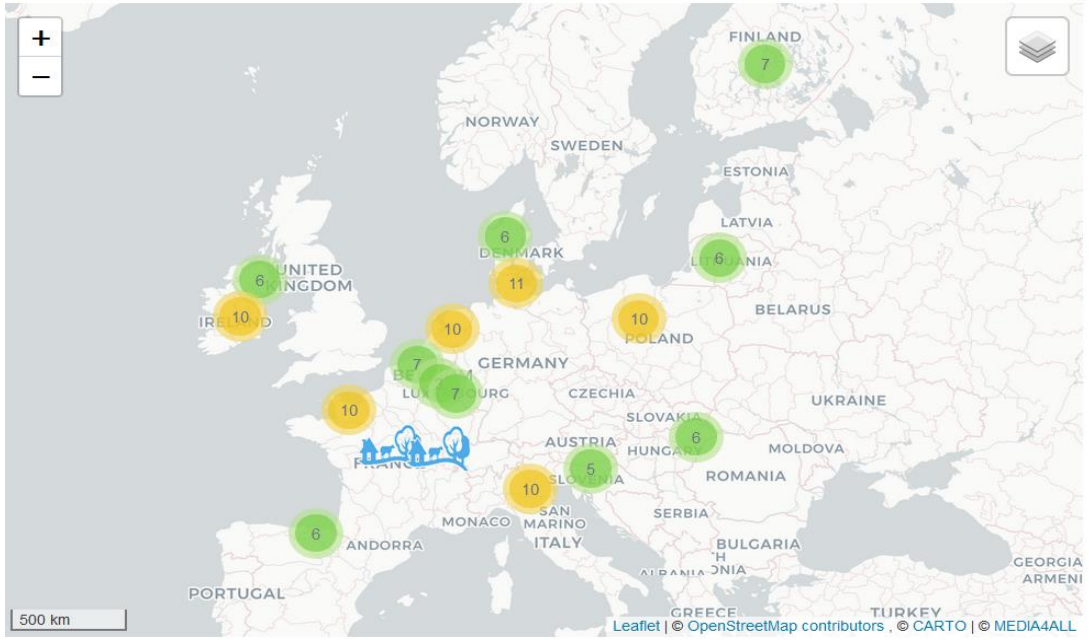
Fist day out on grass in early march 2022

Acknowledgements:

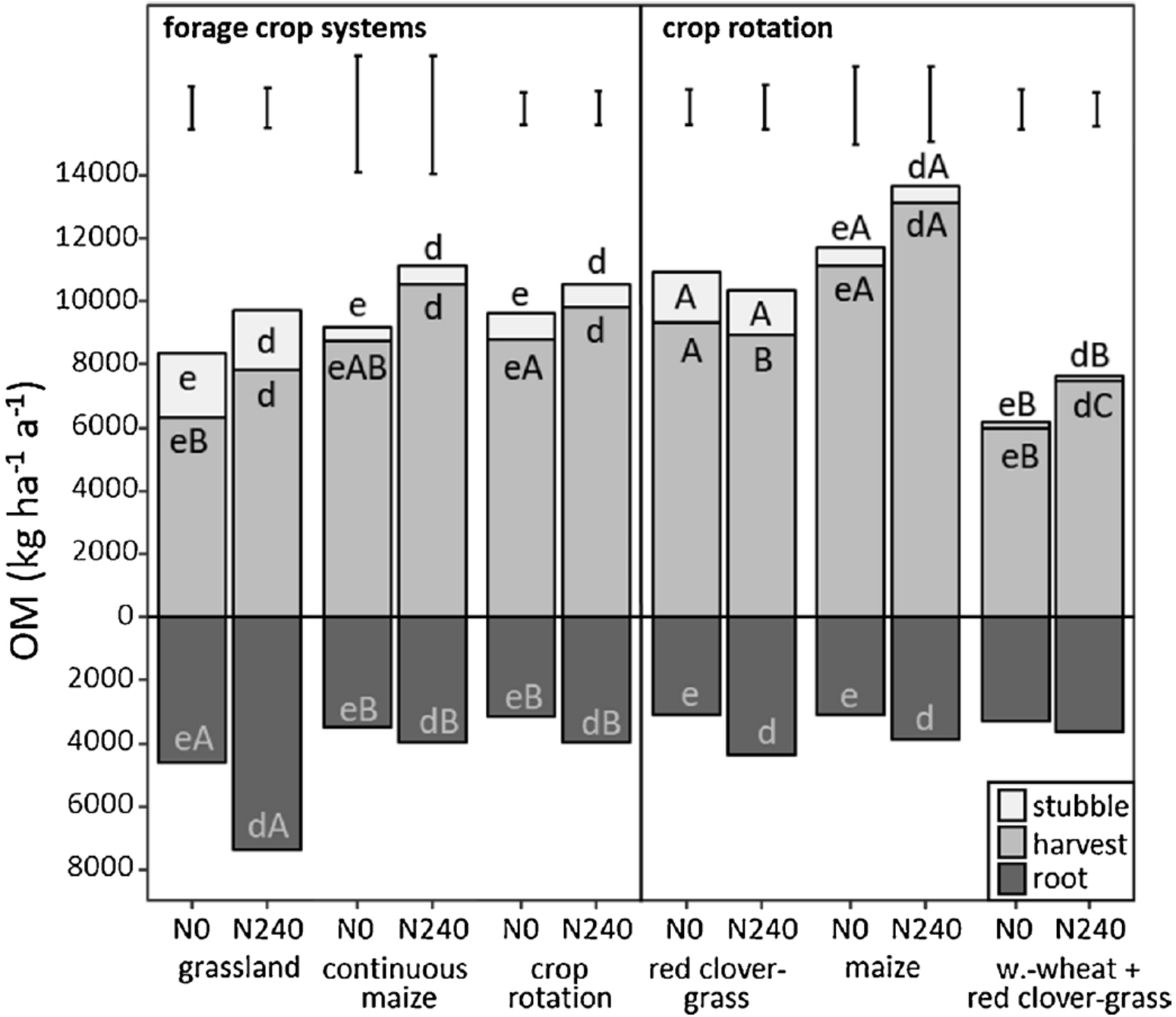
The authors like to thank the EU-Horizon-2020 Project: R4D: Resilience for Dairy (Grant agreement ID: 101000770) for supporting this study

R4D: The European network for sustainable milk production

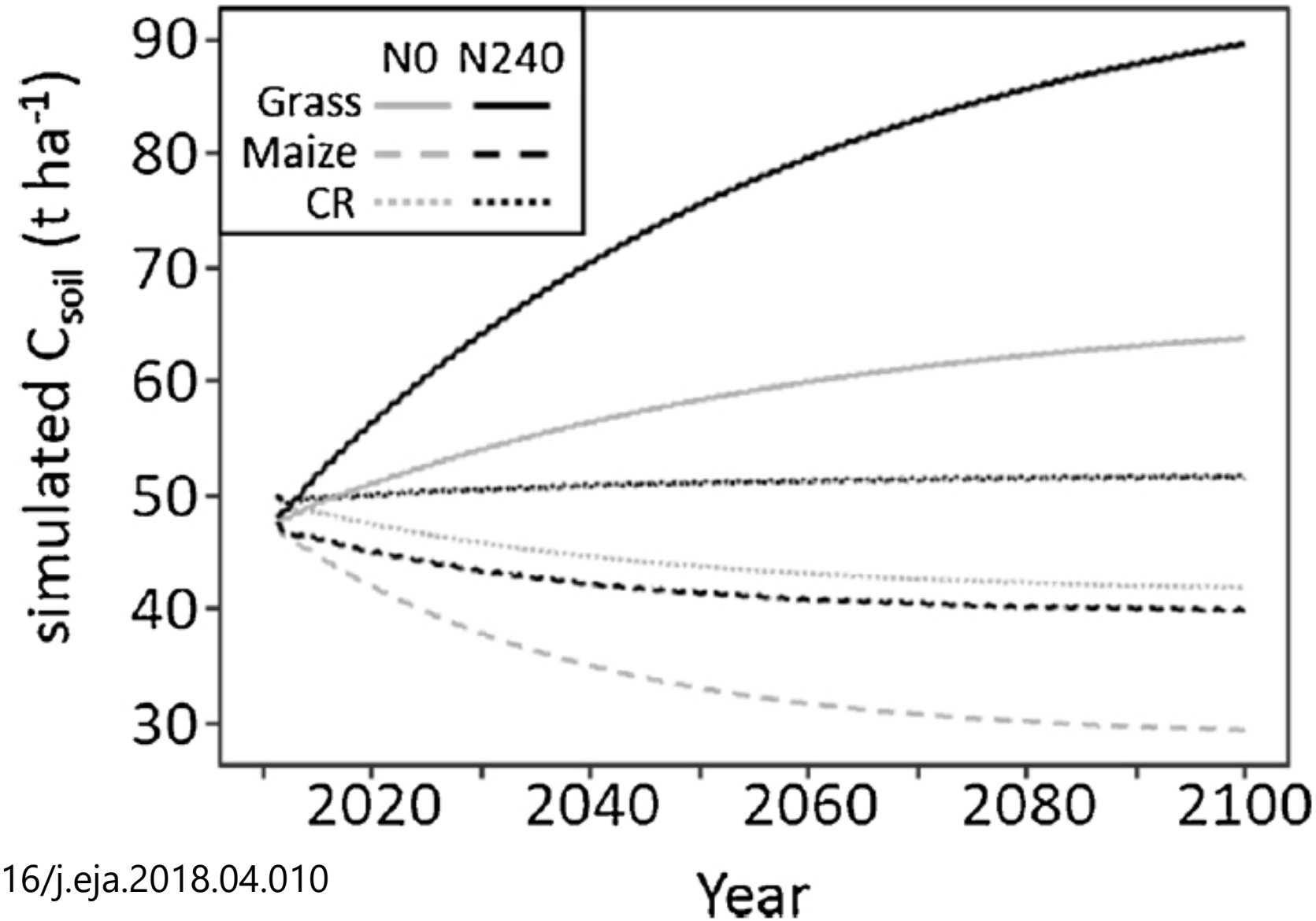
R4D is an international network funded by the EU as part of the Horizon 2020 program that aims to promote the economic, social and environmental sustainability of the dairy industry in Europe. (https://resilience4dairy.eu/)



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