EGF Symposium, Vilnius, 12.06.2023

Kiel University
Christian-Albrechts-Universität zu Kiel




Eco-efficiency of Leys in Dairy Farming Systems

Friedhelm Taube[1,2], John Nyameasem[1], Friederike Fenger[1], Lianne Alderkamp[2], Ralf Loges[1]

[1]Group Grass and Forage Science/Organic Agriculture (GFO) Christian-Albrechts-University Kiel, Germany

[2]Animal Production Systems Group, Wageningen University & Research, 6708 WD Wageningen, The Netherlands

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Resilience 4 for Dairy

Kiel University
Christian-Albrechts-Universität zu Kiel

Content

- Challenges for European dairy systems
- Eco-efficiency & *ecological intensification*
- Towards multi-functional grass based dairy farming
- Organic agriculture or hybrid systems?
- Conclusion

frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 26 May 2021
doi: 10.3389/fsufs.2021.614348

Online: 26.05.2021

Toward Specialized or Integrated Systems in Northwest Europe: On-Farm Eco-Efficiency of Dairy Farming in Germany

Thorsten Reinsch[1*], Cecilia Loza[1], Carsten Stefan Malisch[1], Iris Vogeler[1,2], Christof Kluß[1], Ralf Loges[1] and Friedhelm Taube[1,3]

[1] Department of Grass and Forage Science/Organic Agriculture, Christian-Albrechts-University, Kiel, Germany, [2] Department of Agroecology, Aarhus University, Tjele, Denmark, [3] Grass Based Dairy Systems, Animal Production Systems Group, Wageningen University (WUR), Wageningen, Netherlands

WAGENINGEN UNIVERSITY
WAGENINGEN UR

The problem: decoupling of crop and livestock farming ends up in high N surplus/ social costs in intensively managed European agriculture

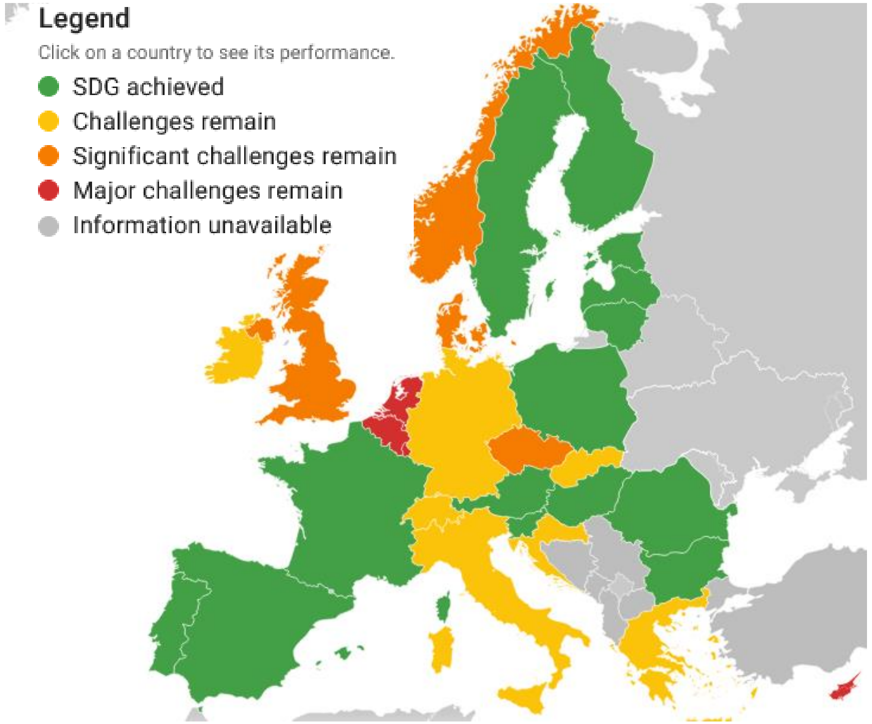
C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

The northern German case: Calculation from different sources: (figures with site to site variation) Taube, 2016

Lit. : Wachendorf et al., 2004; Lampe et al., 2006; Rotz et al., 2005; Kelm et al., 2007, Svoboda et al., 2013; Dittert et al., 2005; Taube et al., 2013; Quackernack et al., 2014; Herrmann et al., 2015; Poyda et al., 2016), Schmeer et al, 2016

N-surplus (kg/ha)	+ 100	€ per kg N:
N- losses leaching (NO_3;NH_4; DON)	- 37	13 (5-24)
N- losses ammonia volatilisation (NH_3)	- 30	14 (4-30)
N- losses N_2O and NOx	- 8	11 (6-18)
N- losses denitrifikation > N2	- 20	
N- sequestration soils (net)	- 5	
Balance:	0	989 € /ha (353 -1932)

Social ‚N costs' of environmental pollution in the EU not accounted for…(average and range according to Brink & van Grinsven, 2011)



… ~ 75% of N surplus directly linked to environmental pollution and **directly linked to animal husbandry** > inducing dramatical social costs-

The challenge: **Ecological intensification** – what does that mean?

WAGENINGEN UNIVERSITY
WAGENINGEN UR

What means ‚ecological intensification'?
Eco-efficiency as a measure

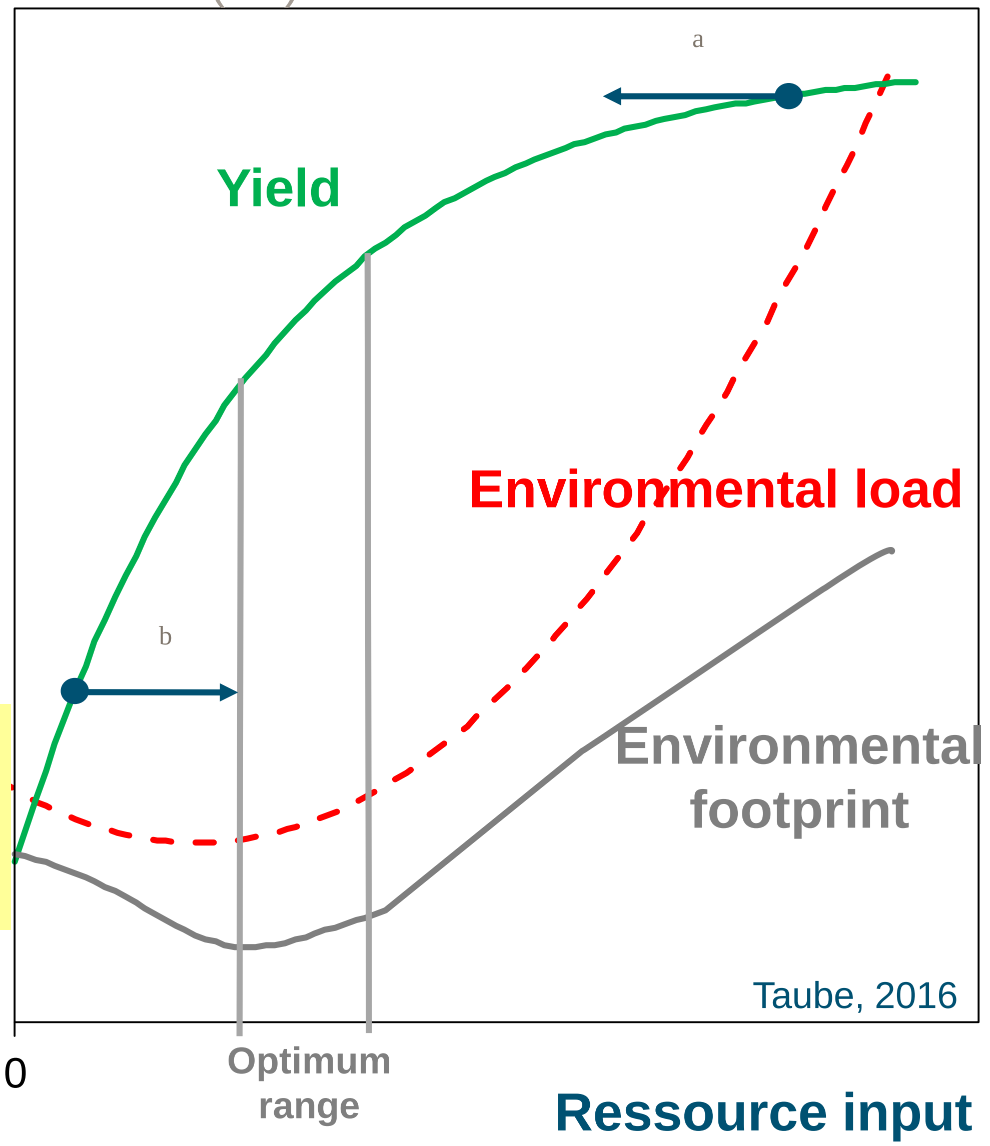
C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

Eco-efficiency of e.g. milk production
related to N input (x) > N surplus > N losses (Y2)

- Y 1 = tons milk/ha
- Y 2 = kg N surplus/ha
- Y 3 = kg N surplus/ton of milk
  (target: less than 10)

Y 3 gives the **N surplus footprint** for a given milk production at a given site

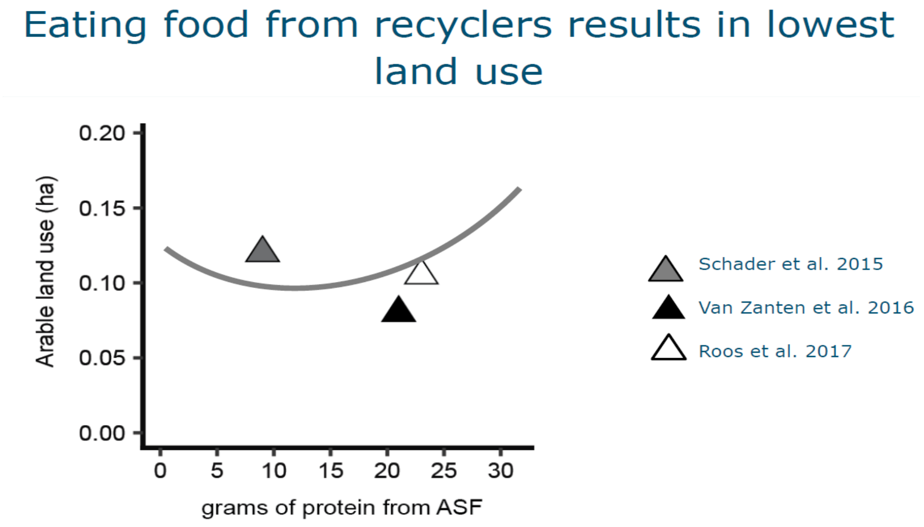
Ecological intensification
a: De-intensifying for common goods
Ecological intensification
b: Intensifying for more food/feed

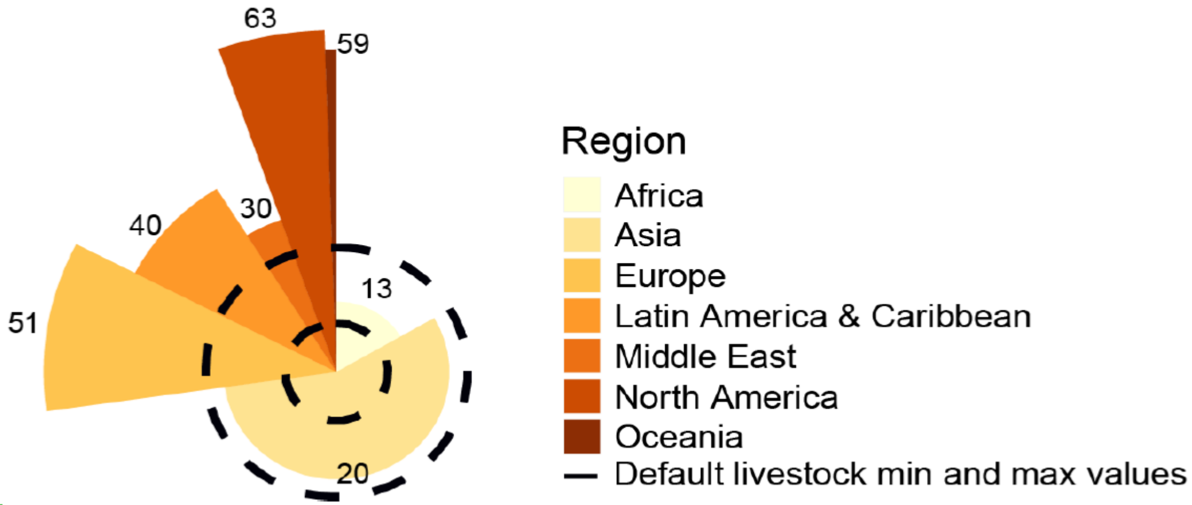


WAGENINGEN UNIVERSITY
WAGENINGEN UR

Environmental pollution x Food security (LUE) x Healthy diets > future ASF: Ecological leftover areas and food from recylers …

Kiel University
Christian-Albrechts-Universität zu Kiel





WAGENINGEN UNIVERSITY
WAGENINGEN UR

Van Zanten et al. 2018a
Defining a land boundary for sustainable livestock consumption
Global Change Biology

…some 13-20% of protein demand per capita per day instead of 50% from ASF are in line with highest LUE > **'circular narrative'**

Consequence: strong reduction of ASF in Europe!

Two 'dairy niches' for highest LUE and social acceptance in Europe: forage for dairy cows from …

1. … **'absolute' permanent grassland**,(but not from peat soils … due to GHG emissions)
2. … **arable land**, if this dairy makes arable cropping systems better **> ley systems** (+pre-cropping effects; +BFN; +no pesticides; …)
3. Towards 'ecological intensification'

e.g. Martin et al., 2020: Role of ley pastures in tomorrow's cropping systems. A review
June 2020 Agronomy for Sustainable Development 40(3)
DOI: 10.1007/s13593-020-00620-9

Challenge:

- **Challenge: Bringing all ES together! Research towards multifunctional grass based dairy farming** (milk + clean water + climate change mitigation + biodiversity + animal welfare + attractive landscapes +…)
- **Offering a data base for future CAP?**
- **Questioning the paradigm of current dairy systems in US/Central Europe:**

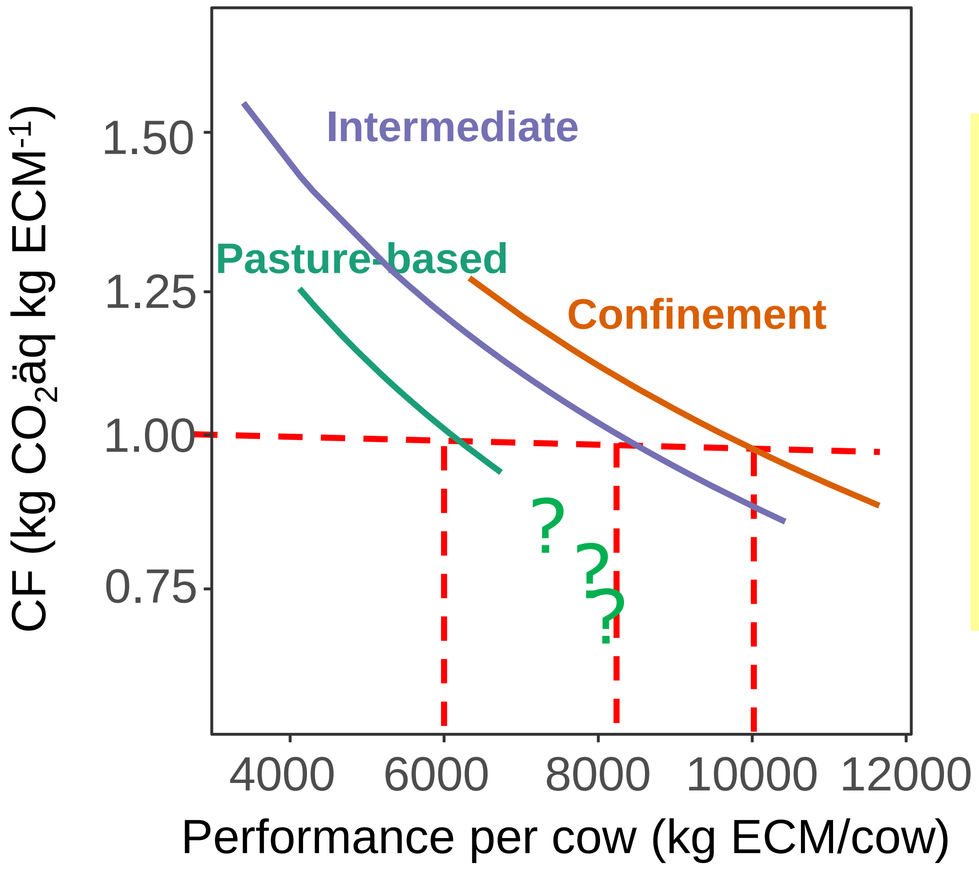
Maximizing milk performance per cow in specialized systems based on maize/concentrate feeding

- **Complementary concept: (Beyond milk production from PG)**

Maximizing milk yield per ha from temporary grassland in ICLS + ES

…how to arrange the experimental design towards system analysis and system optimization?

Starting with a Meta-Analysis for system optimization



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)

High efficiency is reachable at 6000, 8000 and 10000 kg ECM per cow and year within the thresholds of each system.

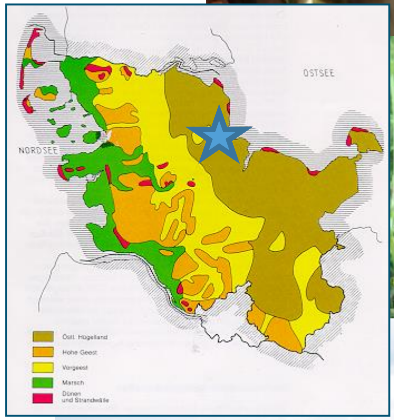
Project: "Eco-efficiency of pasture based milk production"-Experimental farm Lindhof

(precipitation 780 mm, average temp 9,1 °C, T-sum 2100; loamy sand/sandy loam, 150 ha)

C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

Aim: Research towards ICLS > transition of EU agriculture (F2F)

- Maximising milk from grass with low concentrate supplementation in a mixed farming system (ICLS) based on ley systems (here: organic farming)
- At least 75% of milk from grass > Multi-species (8) mixtures for functional diversity & 'home grown proteins' & yield stability & forage quality in 2-3 year ley systems, followed by three years of cash crops
- Rotational grazing (8) +2 silage cuts, block-calving in February
- ~100 cows, Jersey breed, totally sensor equipped/ sexed semen, …
- **Hypothesis:**
- **Win-win-win solutions for farmers, environment, society are feasible:**
- **Milk – NUE – Biodiversity – Carbon Sequestration - Animal Welfare**
- Research: LCA, forage quality, carbon partitioning, optimising pasture management, methane emission, N fluxes, modelling…



WAGENINGEN UNIVERSITY
WAGENINGEN UR

Production figures ICLS Lindhof compared to 350 best performing commercial dairy farms in the state (HF breed; confinement)

C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

Table 1: Production parameters, economic results and nitrogen balance (2019/20) of the experimental farm Lindhof compared to the average of 356 dairy farms fully evaluated by the chamber of agriculture (extension service) of Schleswig-Holstein (Branch accounting of milk production (BZA))

	Unit	Lindhof	Avg. BZA
Dairy herd	number of cows	94	166
Body weight	kg cow^{-1}	470	670[a]
Milk yield	kg ECM cow^{-1}	7,007	9,433
Milk yield natural	kg cow^{-1}	5,728	9,257
Milk yield per kg body weight	kg ECM kg^{-1} BW	14.90	14.08
Milk solids production (fat + protein)	kg cow^{-1}	592	702
Concentrate feeding	dt cow^{-1} $year^{-1}$	8.0	28.1
Concentrate feeding efficiency	g kg^{-1} ECM	120	295
Milk production per ha MFA on farm[b]	kg ECM ha^{-1} MFA	10,946	14,866
Milk produced from forage[c]	kg ECM cow^{-1}	5,284	3,767
Proportion of milk produced from forage[c]	%	75	40
Adjusted reproduction rate	%	18	33
Calving interval (LKV-SH, 2021)	days	362	400[e]
Mineral N fertilizer input	kg N ha^{-1} MFA	0	99
N balance[f]	kg N ha^{-1} MFA	56	149

[a] Estimated value based on the average of the breeds, [b] without area requirements for imported feed; [c] milk from concentrates excluded according to LK-SH (2021) calculation, [d] rearing replacement heifers included, [e] Farms in the same

… costs of forage production?

Abbreviations: SH = Schleswig-Holstein, ECM = energy-corrected milk, MFA = main forage area, BZA = branch accounting, source: LK-SH (2021)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

The economic value of the Lindhof grass-clover -herb mixed system (pasture/silage) compared to indoor dairy systems

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

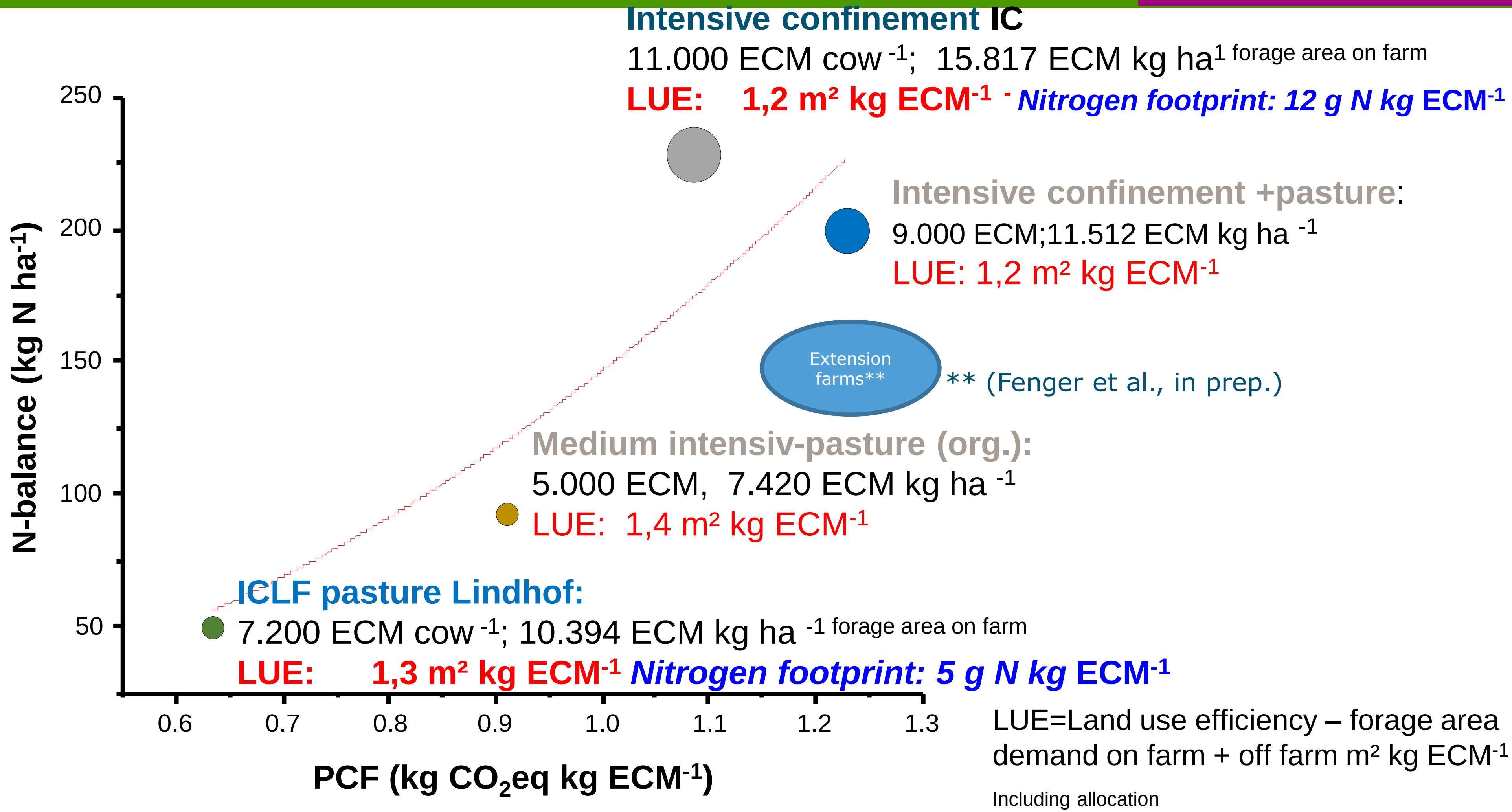
	Lindhof grass-clover-silage	**BZA* grass-silage**	**BZA* maize-silage**
Energy yield (MJ NEL ha^{-1})	57,228	57,593	84,746
Crude protein yield (kg CP ha^{-1})	1,275	1,456	907
Total costs (€ ha^{-1})	944	1,866	2,039
Total cost (ct 10 MJ^{-1} NEL)	16.47	32.40	24.07
Total cost (ct kg^{-1} CP)	0.74	1.28	2.25

*Source: LK-SH (2021), all including land cost;
BZA= Branch accounting of milk production

Very low costs of forage production! Economics work …!

Carbon and nitrogen footprint of milk production systems in NW - Germany

Kiel University
Christian-Albrechts-Universität zu Kiel



(IC: intensive-confinement, SC: semi-confinement,
FG: full-grazing, IFG: integrated full-grazing - Lindhof)

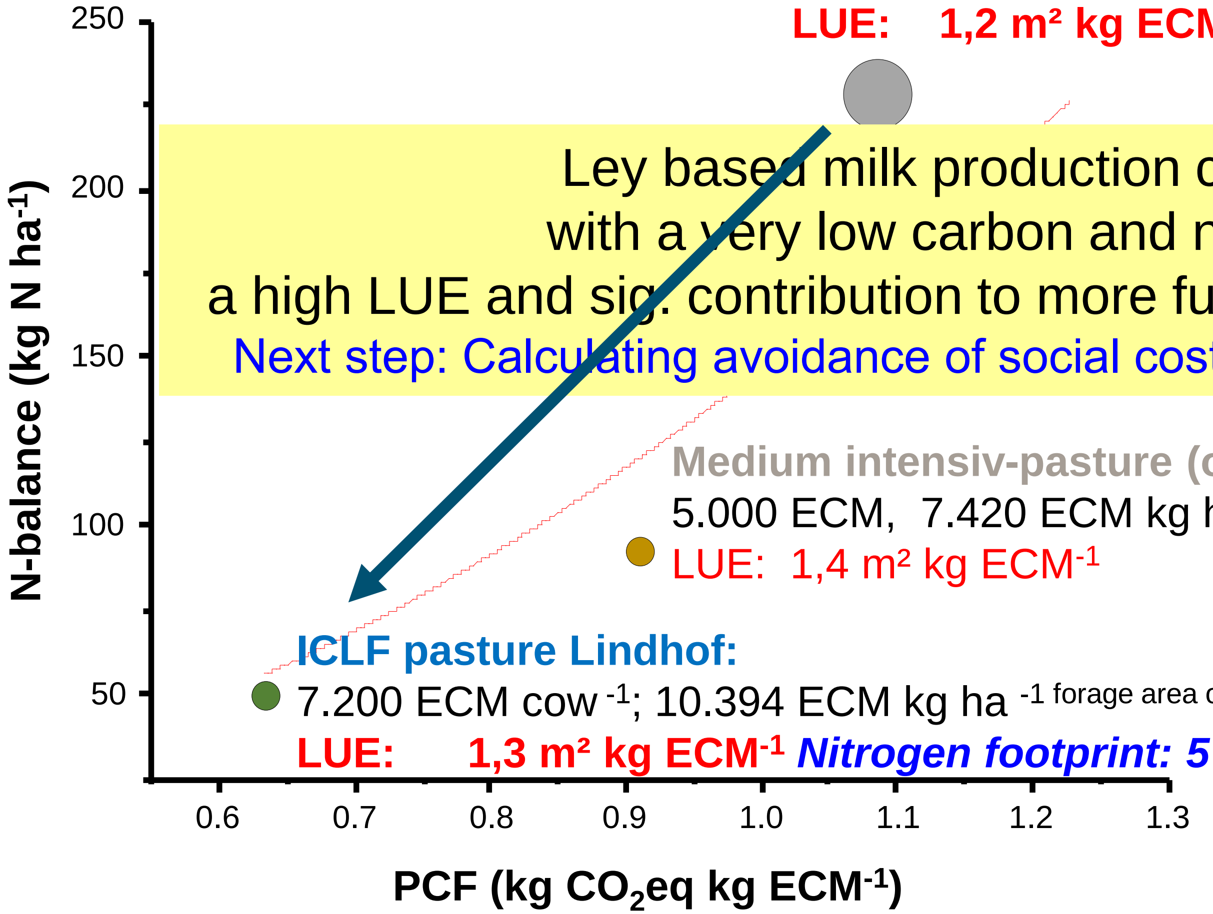
WAGENINGEN UNIVERSITY
WAGENINGEN UR

Reinsch et al. (2021)
Front. Sustain. Food Syst.
https://doi.org/gj68j4

Carbon and nitrogen footprint of milk production systems in NW - Germany

C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

Intensive confinement IC
11.000 ECM cow $^{-1}$; 15.817 ECM kg ha[1] forage area on farm
LUE: 1,2 m² kg ECM^{-1} - ***Nitrogen footprint: 12 g N kg ECM^{-1}***



Ley based milk production can be attributed
with a very low carbon and nitrogen footprint,
a high LUE and sig. contribution to more functional diversity in agriculture!
Next step: Calculating avoidance of social costs of ICLS milk compared to IC …

Medium intensiv-pasture (org.):
5.000 ECM, 7.420 ECM kg ha $^{-1}$
LUE: 1,4 m² kg ECM^{-1}

ICLF pasture Lindhof:
7.200 ECM cow $^{-1}$; 10.394 ECM kg ha $^{-1}$ forage area on farm
LUE: 1,3 m² kg ECM^{-1} ***Nitrogen footprint: 5 g N kg ECM^{-1}***

LUE=Land use efficiency –
forage area demand worldwide m² kg ECM^{-1}

Including allocation

(IC: intensive-confinement, SC: semi-confinement,
FG: full-grazing, IFG: integrated full-grazing - Lindhof)

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Reinsch et al. (2021)
Front. Sustain. Food Syst.
https://doi.org/gj68j4

Avoided environmental costs ICLS verus IC (€ kg^{-1} ECM)

C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

Table 3: Avoided abiotic environmental costs per kg ECM compared between the Lindhof - ICLS system and intensive indoor system IC

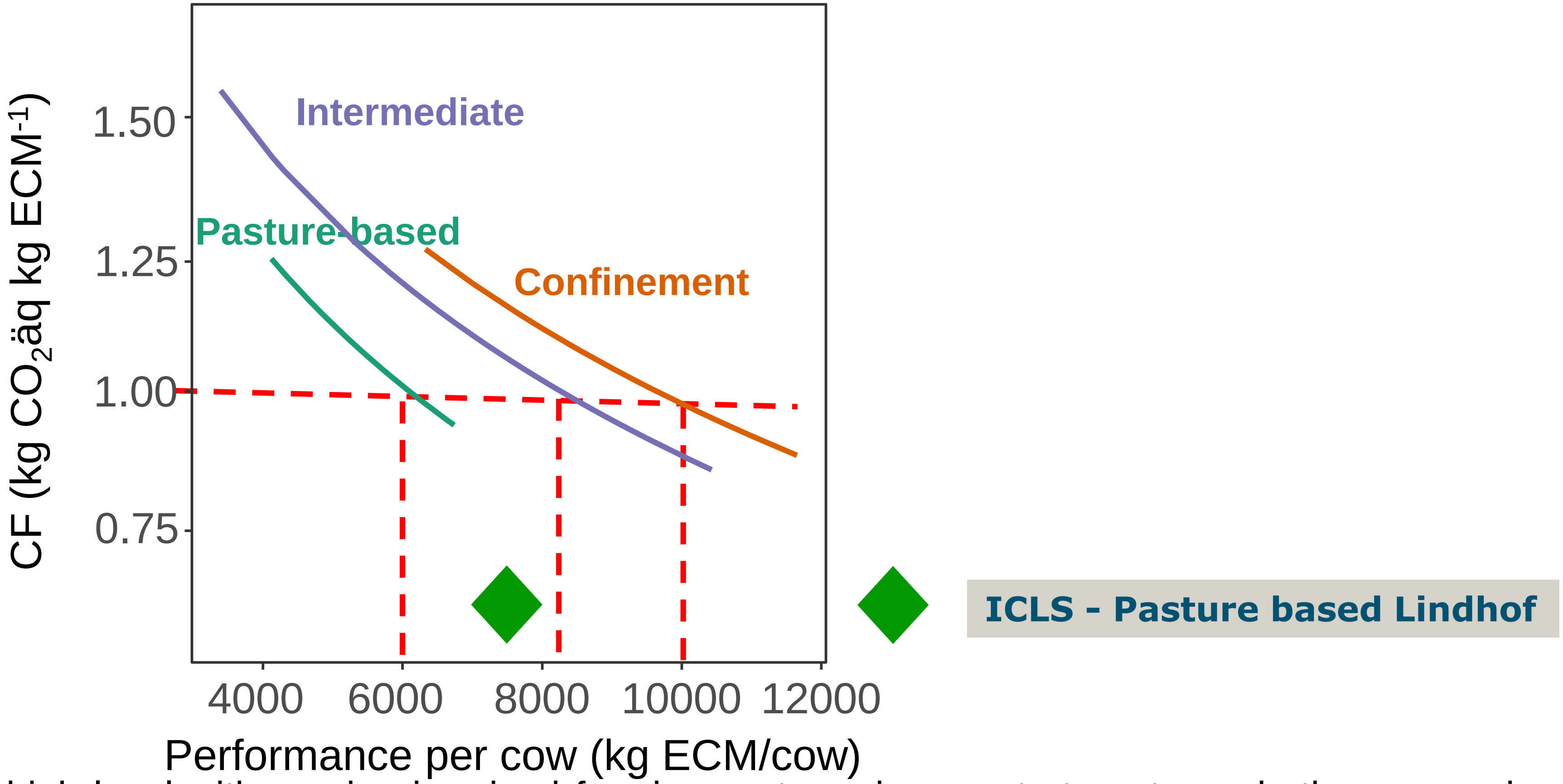
	Indoor dairy	Lindhof	Diff.	Unit cost	Social cost avoided by Lindhof system
GHG (kg CO_2eq kg^{-1} ECM)	1.1	0.6	0.5	100 € t^{-1} CO_2*	0.05 € kg^{-1} ECM
Surplus N (g N kg^{-1} ECM)	12.0	5.0	7.0	10 € kg^{-1} N**	0.07 € kg^{-1} ECM
Surplus P (g P kg^{-1} ECM)	1.2	0.01	1.1	120 € kg^{-1} P***	0.13 € kg^{-1} ECM
				Total	**0.25 € kg^{-1} ECM**

* www.boerse.de/rohstoffe/CO_2-Emission rights price (Sept. 2022)
**European Nitrogen Assessment Report (2013)
*** UBA (2021). https://www.umweltbundesamt.de/tags/phosphor

… specialized all indoor high input/high output milk production systems can be very expensive for the society!

WAGENINGEN UNIVERSITY
WAGENINGEN UR

First Conclusion



- Linking milk production on high level with grazing in mixed farming systems is one strategy towards the economic resilience of (dairy) farming and the provision of long term ES for the society in agricultural landscapes

- Organic farming? Forage/dairy unit …: yes - but not for the cash crop unit > (LUE) - do we need ‚hybrid systems'?

EU-F2F: 25% of Organic Agriculture (OA) in the EU? Or better some ~10% OA and 15% and even more ‚hybrid agricultural systems (Taube, 2020)

C | A | U
Kiel University
Christian-Albrechts-Universität zu Kiel

Hybrid agriculture 1.0 **(Taube, 2020)**

Bringing together the very best of two worlds (conventional/organic) e.g. in a 6 –year crop rotation ensuring high LUE and ecological intensification !

+ ‚virtual mixed farming systems'

(cooperation between specialized dairy and cash crop farms with common land use)

Example:

1. Part (close to organic > no pesticides/ no mineral N fertilizer)

- 2 year grass-clover herb leys
- Spring crop (oats/maize

2. **Part (conventionelly managed cash crops**

- Winter wheat
- Oil seed rape
- …

Hybrid agriculture projects started at CAU Kiel (experiments) and WUR (modelling)

1:1 transformation towards F2F – strategy!

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Final Conclusion

Kiel University
Christian-Albrechts-Universität zu Kiel

- Eco-efficiency of land use systems can be improved by ruminants consuming primarily residues and grassland products from PG and leys!

(Reseach-) **Questions:**

- Are better certification measures needed for those systems (e.g. **‚grass milk'** ensuring that at least 75% of protein and energy in the diet is coming from grass)?
- Does LCA methodology cover the full buqet of benefits of ley systems (…more than PCF!)?
- Is more research needed to quantify the social costs of high input/high output systems?
- How to implement benefits of ley systems in the CAP (e.g. Public Goods bonus) ?

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Thank you for your attention

Kiel University
Christian-Albrechts-Universität zu Kiel

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

European Commission