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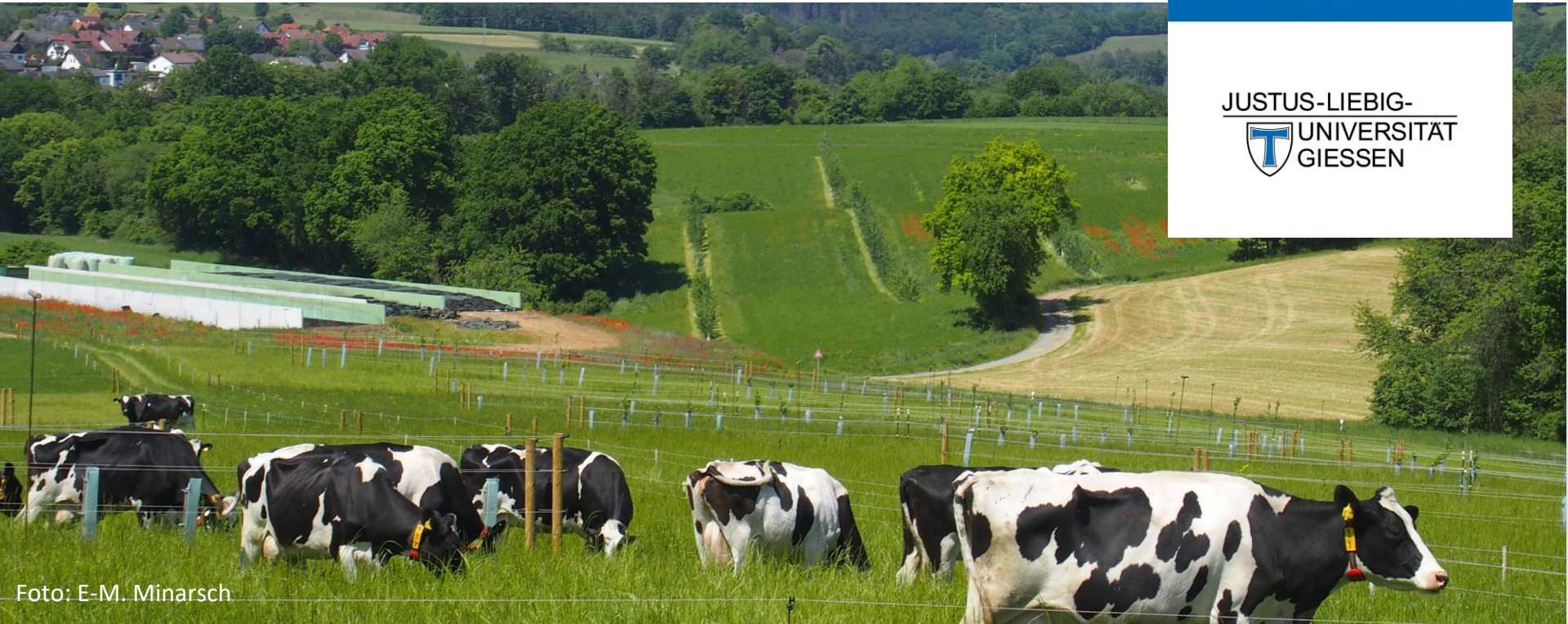


Foto: E-M. Minarsch

Eco-functional intensification and circularity through organic soil-crop-livestock systems

Deise Aline Knob
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Where we are



High productivity gains in German agriculture...

+283%



Ernteertrag für 1 ha Weizen (Winterweizen einschl. Dinkel und Einkorn)

1950*:	2.580 kg
1980*:	4.890 kg
Durchschnitt 2017–19:	7.303 kg



Ernteertrag für 1 ha Kartoffeln

1950*:	24.490 kg
1980*:	25.940 kg
Durchschnitt 2017–19:	40.400 kg

+333%



Milchleistung pro Kuh und Jahr

1950*:	2.480 kg
1980*:	4.538 kg
2019:	8.250 kg



Legeleistung einer Henne pro Jahr

1950*:	120 Eier
1980*:	242 Eier
2019:	298 Eier

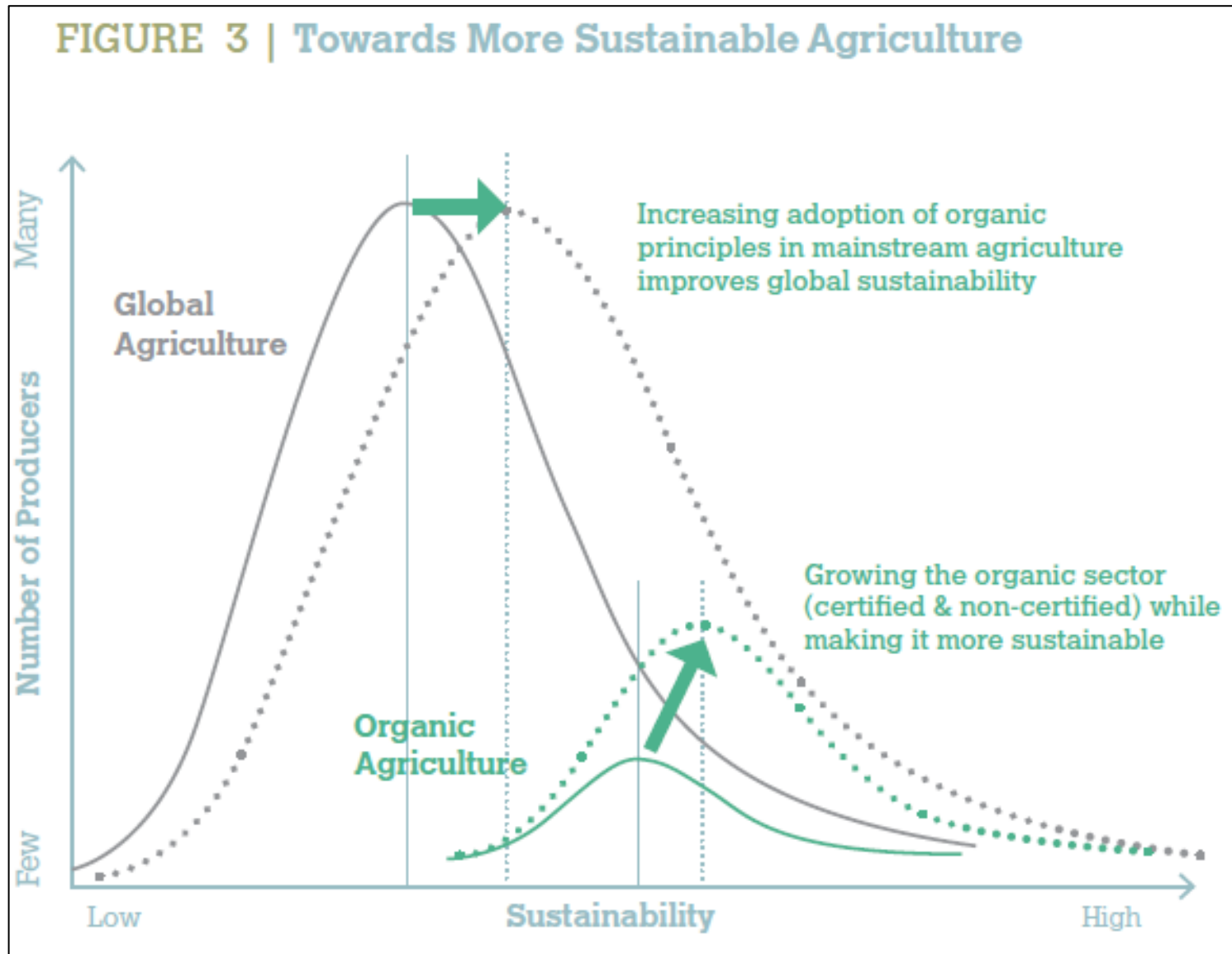
* früheres Bundesgebiet

...but at the expenses at high external costs! (ZKL, 2021):

(21bn € < 90bn €)



Organic farming as role model for agricultural transformations



Eco-functional intensification and circularity through organic soil-crop-livestock systems

1. Success story organic farming
2. „Standard“ (organic) farming is not enough!
3. Eco-functional intensification and circularity through improved organic cropping systems
4. The potential of integrated animal-plant agricultural systems: developing agriculture and food within planetary boundaries



Eco-functional intensification and circularity through organic soil-crop-livestock systems

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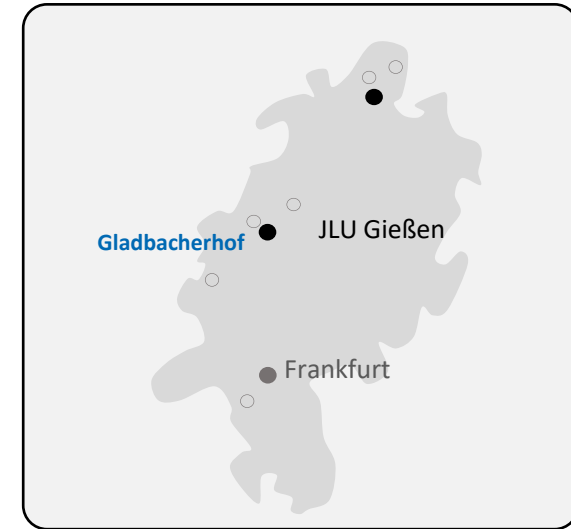


Research Farm Gladbacherhof

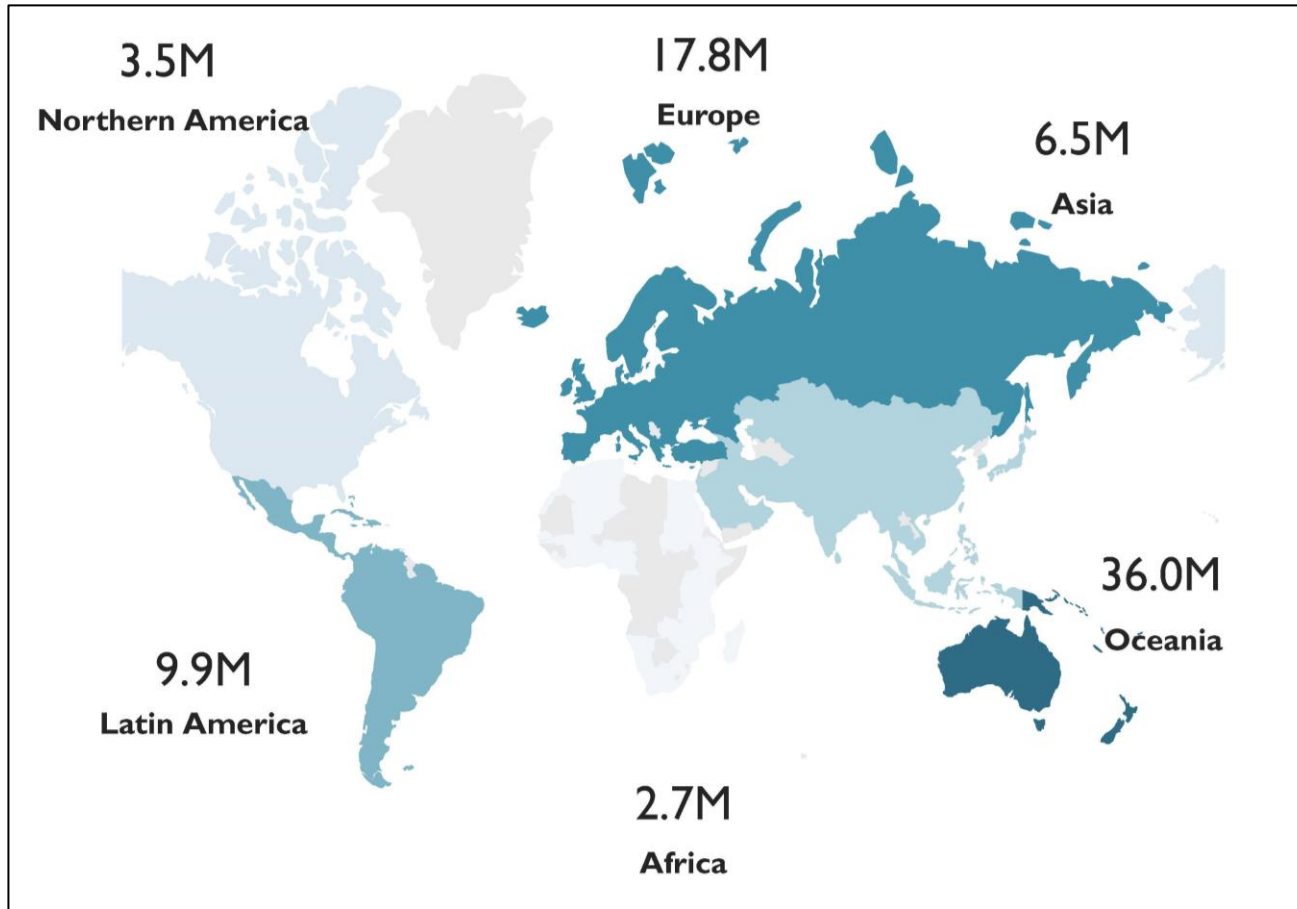
- Agricultural Teaching and Research Facility for Organic Farming at the JLU Gießen (since 1990)
- Mixed-use farm in a mid-mountainous area
- (9.5°C average annual temperature, 655 mm annual precipitation)
- 110 hectares of arable land, 77 hectares of permanent grassland
- 8-year crop rotation with maize cultivation

Operation Focus Areas:

- Dairy cattle (100 Holstein-Friesian cows with 8,500 kg of milk per cow per year), breeding goal: lifetime performance
- Seed and plant material production
- Laying hens (mobile chicken coops)
- direct sales to customers



Global: Organic farming area

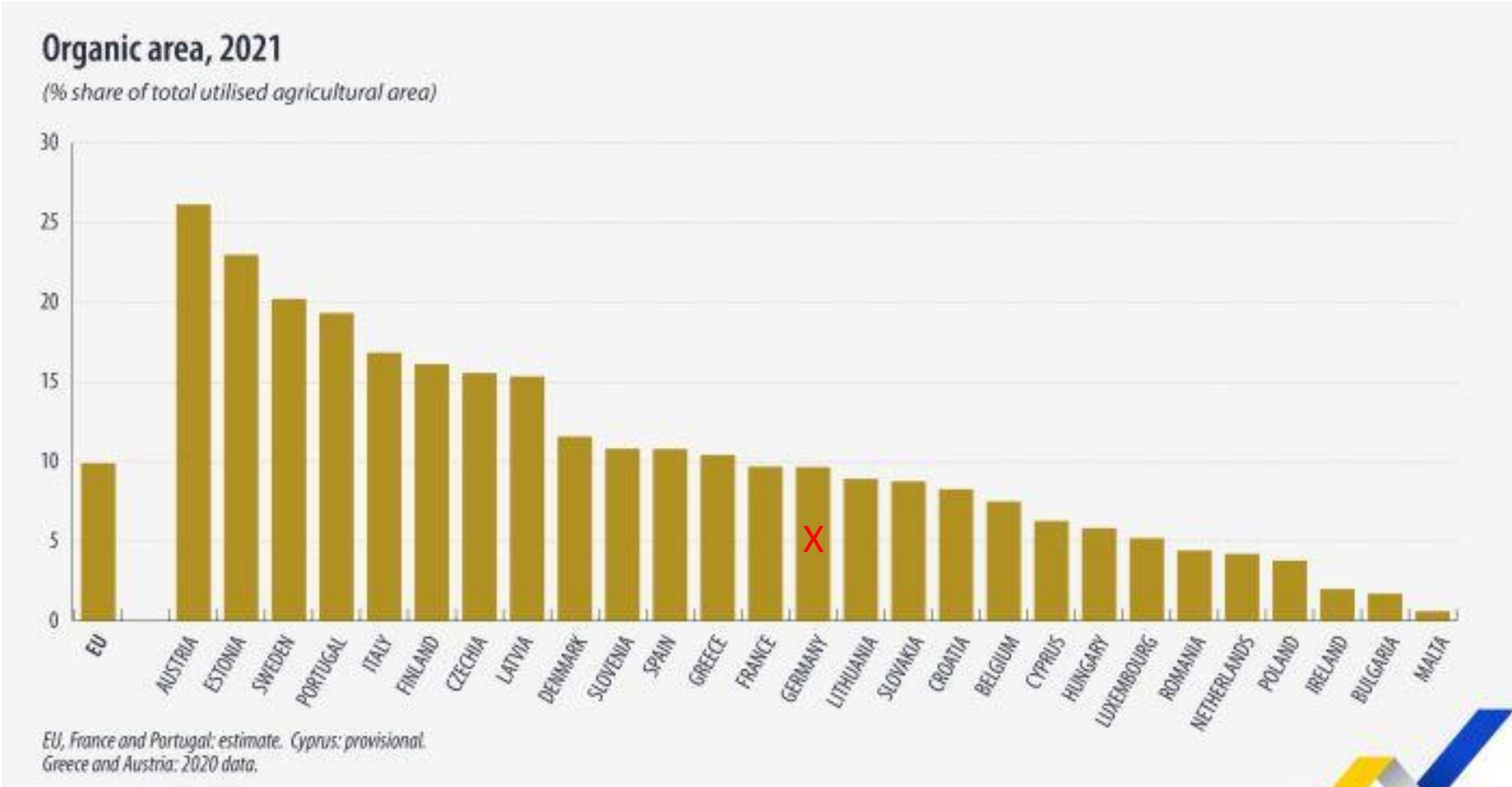


(in M= million hectares; in total 76.4M, 1.6.% of farmed land)

Source: FiBL survey 2023

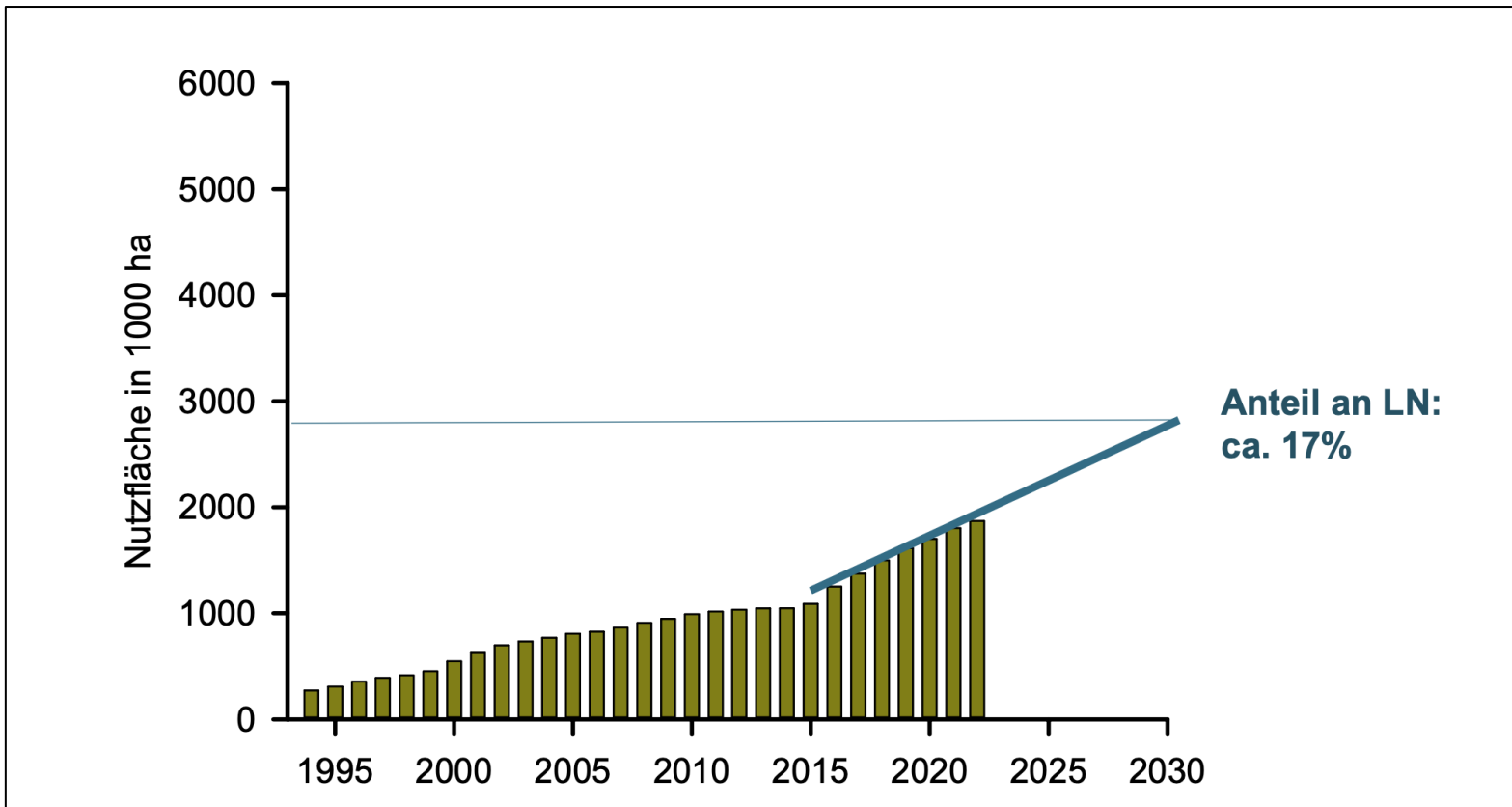
Organic Farming in Europe

EU-target: 25% organic farming area by 2030



Ambitious targets for organic farming...

Target: 30% organic farming in Germany by 2030



Development of organic farming area in Germany including projection 2030 (assumed constant growth rate); (BMELV 2022, BÖLW 2023)

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Organic Agriculture – the benefits for ecosystems and society

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

The impact of long-term organic farming on soil-derived greenhouse gas emissions

Colin Skinner¹, Andreas Gattinger^{1,2}, Malke Krauss¹, Hans-Martin Krause¹, Jochen Mayer¹, Marcel G. A. van der Heijden^{1,3,4} & Paul Mäder¹

Agricultural practices contribute considerably to emissions of greenhouse gases. So far, knowledge on the impact of organic compared to non-organic farming on soil-derived nitrous oxide (N₂O) and methane (CH₄) emissions is limited. We investigated N₂O and CH₄ fluxes with manual chambers during 371 days in a grass-clover-sludge maize – green manure cropping sequence in the long-term field experiment 'SoilCult'.

Enhanced top soil carbon stocks under organic farming

Andreas Gattinger¹, Adrian Müller¹, Matthias Haen^{1,2}, Colin Skinner¹, Andreas Fliessbach¹, Nina Buchmann¹, Paul Mäder¹, Matthias Stolze¹, Peter Smith¹, Nadia El-Hage Scialabba¹, and Urs Niggli¹

¹Swiss Institute of Organic Agriculture, 5070 Frick, Switzerland; ²Institute of Agricultural Sciences, Eidgenössische Technische Hochschule Zurich, 8052 Zurich, Switzerland; ³Institute of Biological and Environmental Sciences, University of Aberdeen, Aberdeen AB24 3JJ, Scotland; and ⁴Natural Resources Management and Environment Department, Royal and Agricultural University of the United Kingdom, 601 95J, Reading, UK

PLOS ONE

Organic farming enhances soil microbial abundance and activity—A meta-analysis and meta-regression

Marlene Lor^{1,2,3}, Sarah Symmach¹, Paul Mäder¹, Gerlinde De Deyn¹, Andreas Gattinger^{1,2}

¹ Department of Soil Sciences, Research Institute of Organic Agriculture (FiBL), Frick, Switzerland; ² Karl-Glockner-Str. 21 C, Justus-Liebig University Gießen, Gießen, Germany; ³ Department of Soil Quality, Wageningen University, Wageningen, The Netherlands

SCIENTIFIC REPORTS

Reduced temperature

M. Krauss^{1,2}, K. Haagsma¹, L. Vincent¹

¹ Research Institute of Organic Agriculture (FiBL), Adenaustrasse 21, 5070 Frick, Switzerland; ² Swiss Institute of Organic Agriculture, 5070 Frick, Switzerland; ³ Swiss Institute of Organic Agriculture, 5070 Frick, Switzerland

Science of the Total Environment: 488–499 (2014) | 533–543

Science of the Total Environment

journal homepage: www.nature.com/scientificreports

Greenhouse gas fluxes from agricultural soils under organic and non-organic management – A global meta-analysis

Colin Skinner¹, Andreas Gattinger^{1,2}, Adrian Müller¹, Paul Mäder¹, Andreas Fliessbach¹, Matthias Stolze¹, Reiner Ruser¹, Urs Niggli¹

¹ Swiss Institute of Organic Agriculture (FiBL), Adenaustrasse 21, 5070 Frick, Switzerland; ² Swiss Institute of Organic Agriculture, 5070 Frick, Switzerland; ³ Institute of Crop Science, University of Göttingen, Postfach 30 1508, 30559 Göttingen, Germany

Reduced temperature

M. Krauss^{1,2}, K. Haagsma¹, L. Vincent¹

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ISME

Agricultural intensification reduces microbial network complexity and the abundance of keystone taxa in roots

Samiran Banerjee¹, Florian Walder¹, Lucie Büchi^{1,2}, Marcel Meyer¹, Alain Y. Held¹, Andreas Gattinger^{1,3}, Thomas Keller^{1,4}, Raphael Charlet^{2,5}, Marcel G. A. van der Heijden^{1,6}

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Introduction

Agricultural intensification is one of the most pervasive problems of the twenty-first century [1]. To keep pace with the ever-increasing human population, the total area of cultivated land worldwide has increased over 500% in the last five decades [2] with a 700% increase in the fertilizer use and a several-fold increase in pesticide use [3, 4]. Agricultural intensification has raised a wide range of

These authors contributed equally: Samiran Banerjee, Florian Walder

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⁸ Department of Plant and Microbial Biology, University of Zurich, 8008 Zurich, Switzerland

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ORGANIC FARMING, CLIMATE CHANGE MITIGATION AND BEYOND

REDUCING THE ENVIRONMENTAL IMPACTS OF EU AGRICULTURE

Jörn Sanders, Jürgen Heß (Hrsg.)

IFAM EU GROUP

MAKING EUROPE MORE ORGANIC

FiBL

Leistungen des ökologischen Landbaus für Umwelt und Gesellschaft

Thünen Report 65

SPRINGER NATURE

Enhanced microbial biomasses and N transformation activities in soils under organic farming (global meta-analysis)

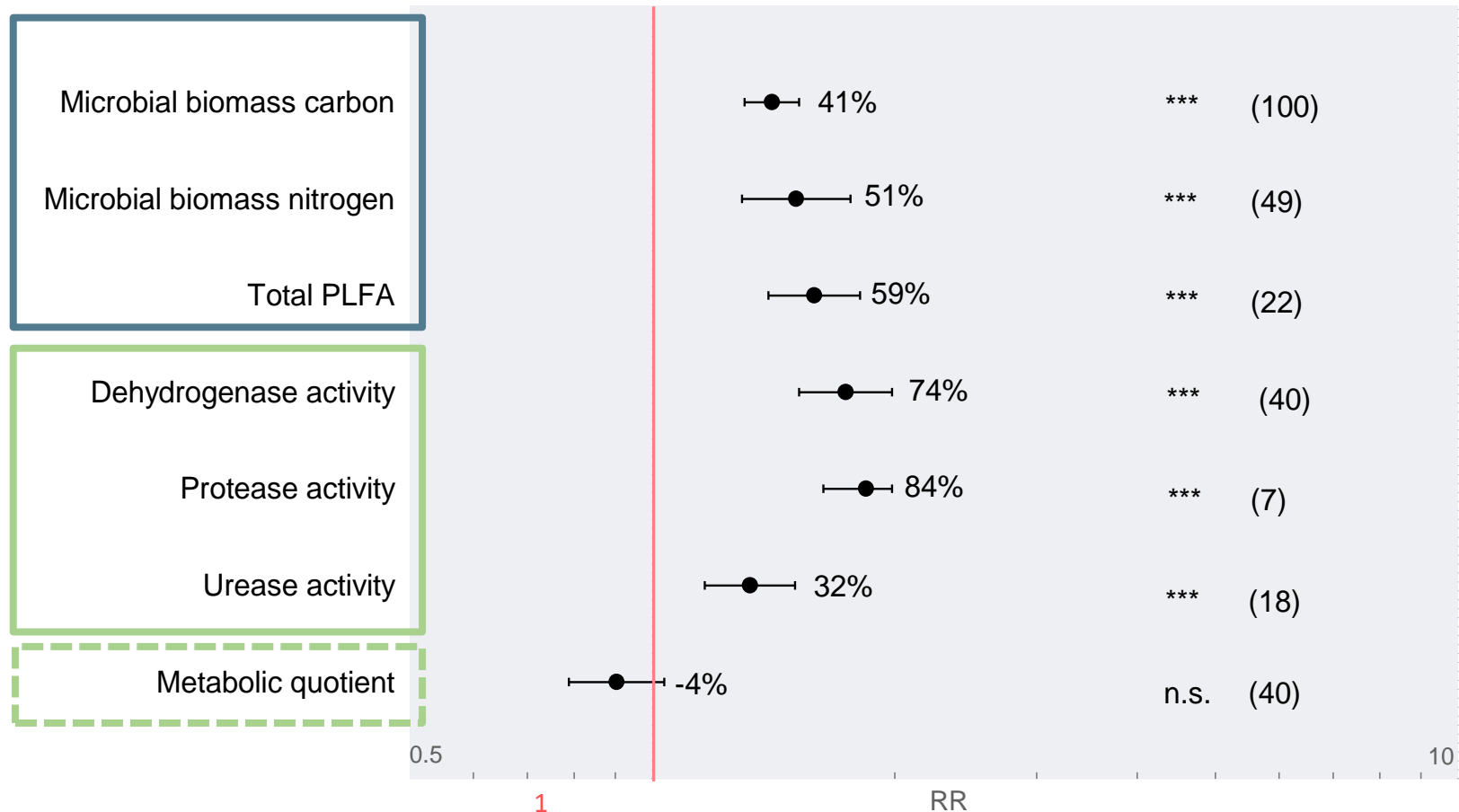


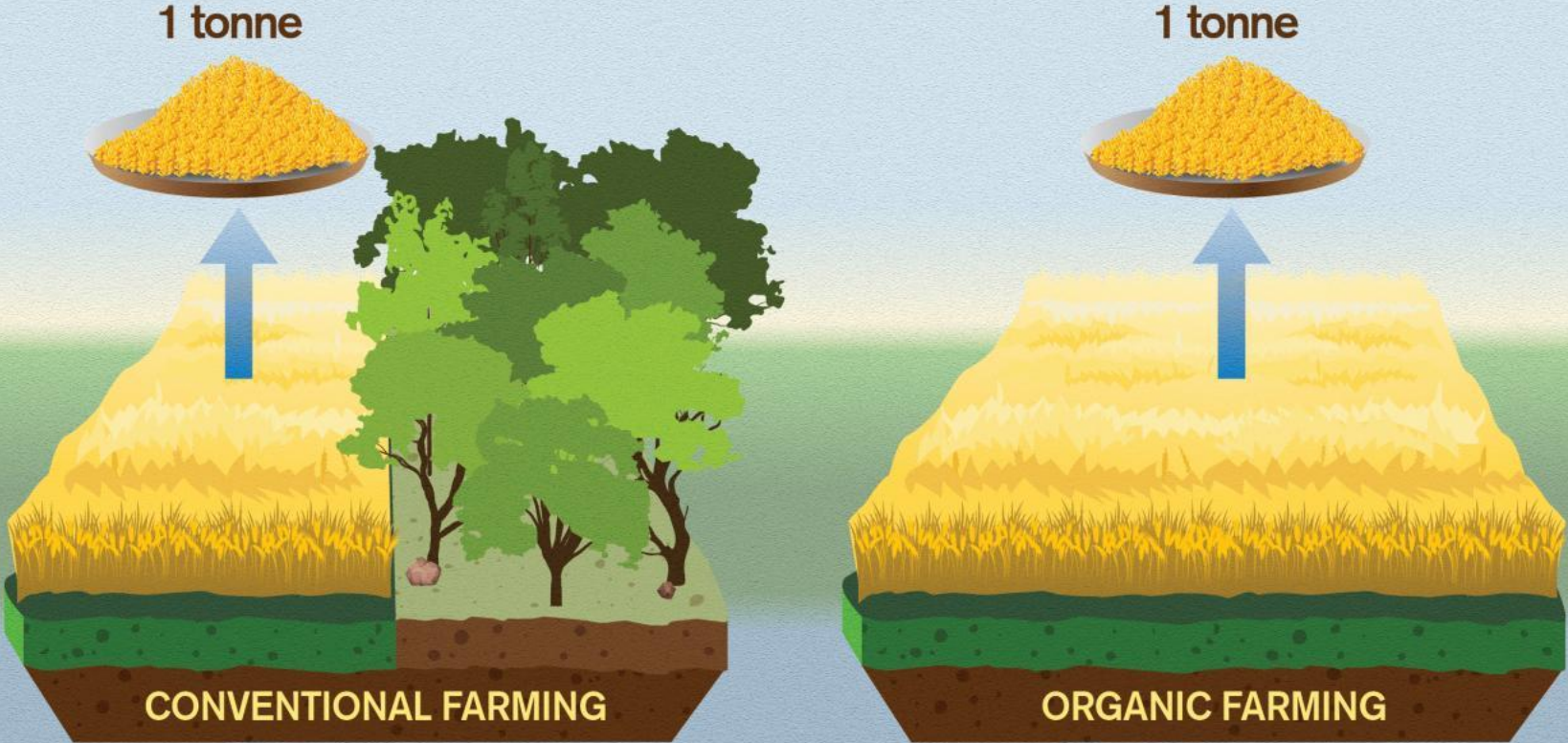
Figure 3: Summary of overall response ratios (RR). Random effects model with a Z-Distribution and a 95 % confidence interval was applied on eight target variables listed on the y-axis. The red line (RR=1) indicates no difference between organic and conventional systems. X-axis is given in log-scale as indicated with grey numbers. Numbers in brackets display the number of pairwise comparisons included in each calculation. Numbers beside the confidence intervals indicate the overall percentage difference per target variable. * ≥ 0.05 , ** ≥ 0.01 , *** ≥ 0.001 , n.s.=not significant

Productivity and ecosystem services in organic agriculture (in comparison to conventional) – in short

- Enhanced **soil life** (Lori et al. 2017; Lichtenberg et al. 2017; Hess & Sanders, 2019)
- Enhanced **carbon stocks** in organic farming (Gattinger et al. 2012; Aguilera et al. 2013)
- Less area-scaled and equal/lower yield scaled **GHG emissions** (Skinner, Gattinger et al. 2014 & 2019; Chiriaco et al. 2022)
- Higher above-ground **diversity** (Stein-Bachinger et al. 2021)
- Equal **animal welfare** (health, behaviour, emotions) (Brinkmann et al. 2019)
- Equal **food quality**, lower abundance of unwanted residues (Baranski et al. 2013)

- **But lower yields:**
Globally: -9 to -25% (Seufert et al. 2012, De Ponti et al. 2012, Ponisio et al. 2015, Wilbois & Schmidt, 2019)
Germany: -20 to -43% (Noleppa 2016, Treu et al. 2017, BMEL 2019)

Organic Farming and the long shadow of less yield...



Assessing the efficiency of changes in land use for mitigating climate change (Searchinger et al. Nature, 2018)

Long-term organic farming and soil quality

(DOK Trial Switzerland, *1977)



Conventional (CONMIN)



Organic (BIODYN)

Water retention of arable soils after heavy rain (20 mm/h)

DOK Trial Switzerland



Conventional (CONMIN)



Organic (BIODYN)

Low resilience against extreme rainfall

(110 mm/h on 5th July 2018) despite 35 years of organic farming at Gladbacherhof, Germany



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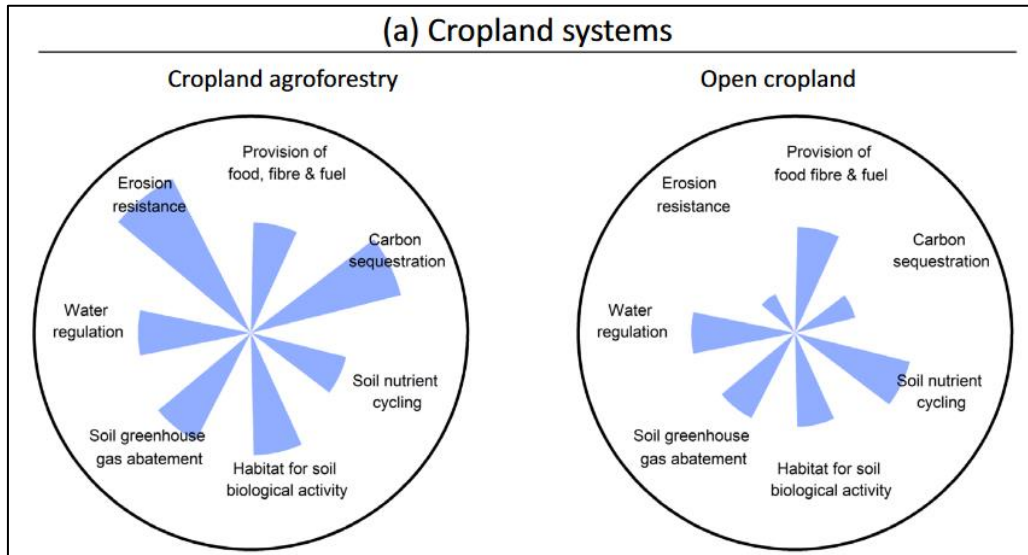


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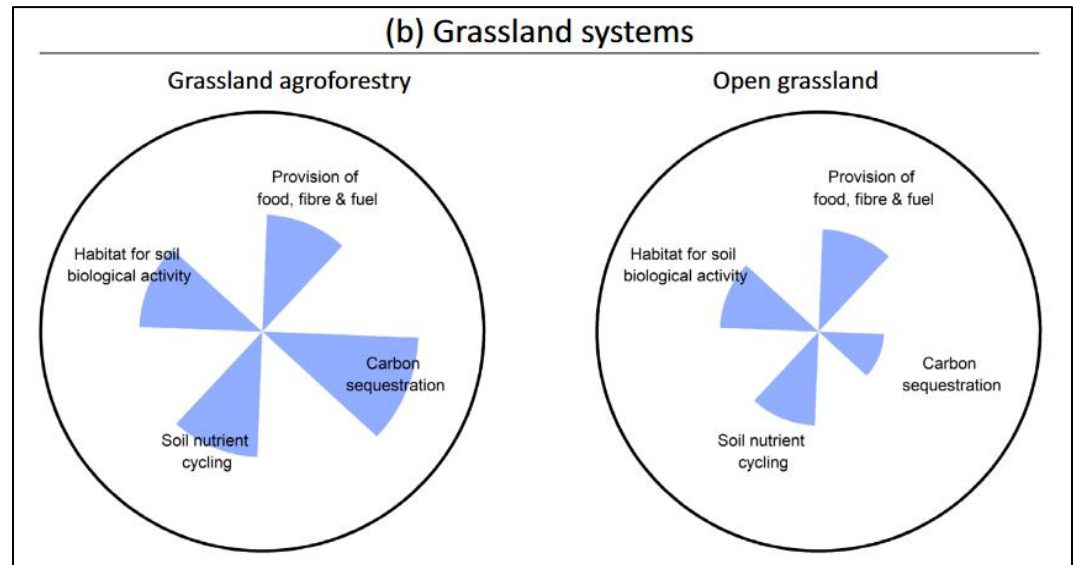
- Closing the yield and efficiency gaps according to best ecological and agronomic practice
- Targeted use of natural processes and ecosystem services for improved resilience
- Close integration of crop production and animal husbandry
- Symbioses, synergies, multidimensionality including bioeconomy

Agroforestry, ecosystem services and resilience

(a) Cropland systems



(b) Grassland systems



Agroforestry Systems Hessen at Gladbacherhof (GH1-GH3)



	GH1	GH2	GH3
Type	Silvoarable	Silvopastoral	Silvoarable
Main aims	Erosion reduction + WP products	Shade for animals + WP products	Water retention + WP products
Establishment	February 2020	November 2021	November 2022
Size [ha]	3.5	8.0	3.3
Slope orientation	North-West	North-East	North
Slope [grade]	0.2-31.0, Ø 6.6	0.5-24.0, Ø 6.9	0.1-18.0, Ø 6.4
TS orientation	North-South	East-West	East-West
TS number	6	34	6
TS width [m]	3	2	4
AS width [m]	18	21	18
TS total length [m]	986	1900	771
TS share [%]	8.5	4.8	9.4
Number of trees	786	612	503



Agroforestry Systems at Gladbacherhof



Silvopastoral Agroforestry System

Agroforestry System

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Mulch vegetable farming

- Planting vegetables in a mulched biomass system facilitates open-field vegetable production without the need for irrigation
- This approach also promotes increased soil carbon retention and reduces greenhouse gas emissions, enhancing sustainability in agriculture

Saat einer geeigneten Zwischenfrucht

- Gemenge aus Grünschnittroggen-Zottelwicke- Erbse (60;20;20)
- Benötigt ca. die geplante Gemüsefläche x Faktor 2 (zzgl. 100 %)

Mulchen und Nachstreuen

- Geräte: Schlegelmulcher, Ladewagen mit Streuwerk
- Ziel: min. 15 t TM ha⁻¹

Pflanzung der Jungpflanzen

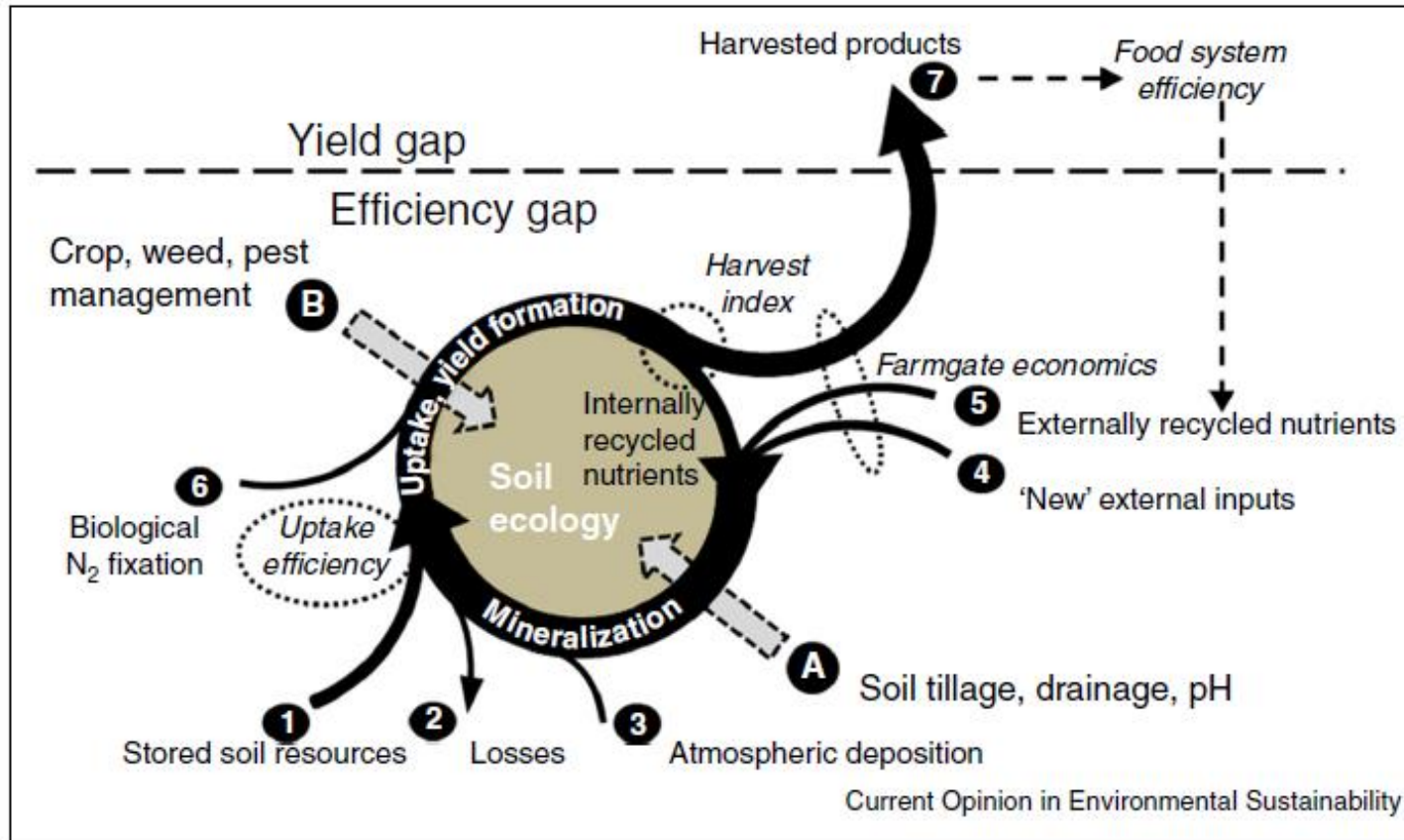
- Pflanzung mit spez. Pflanzmaschine („MulchTec“)



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Future research and development: eco-functional intensification to make use of the soils potential



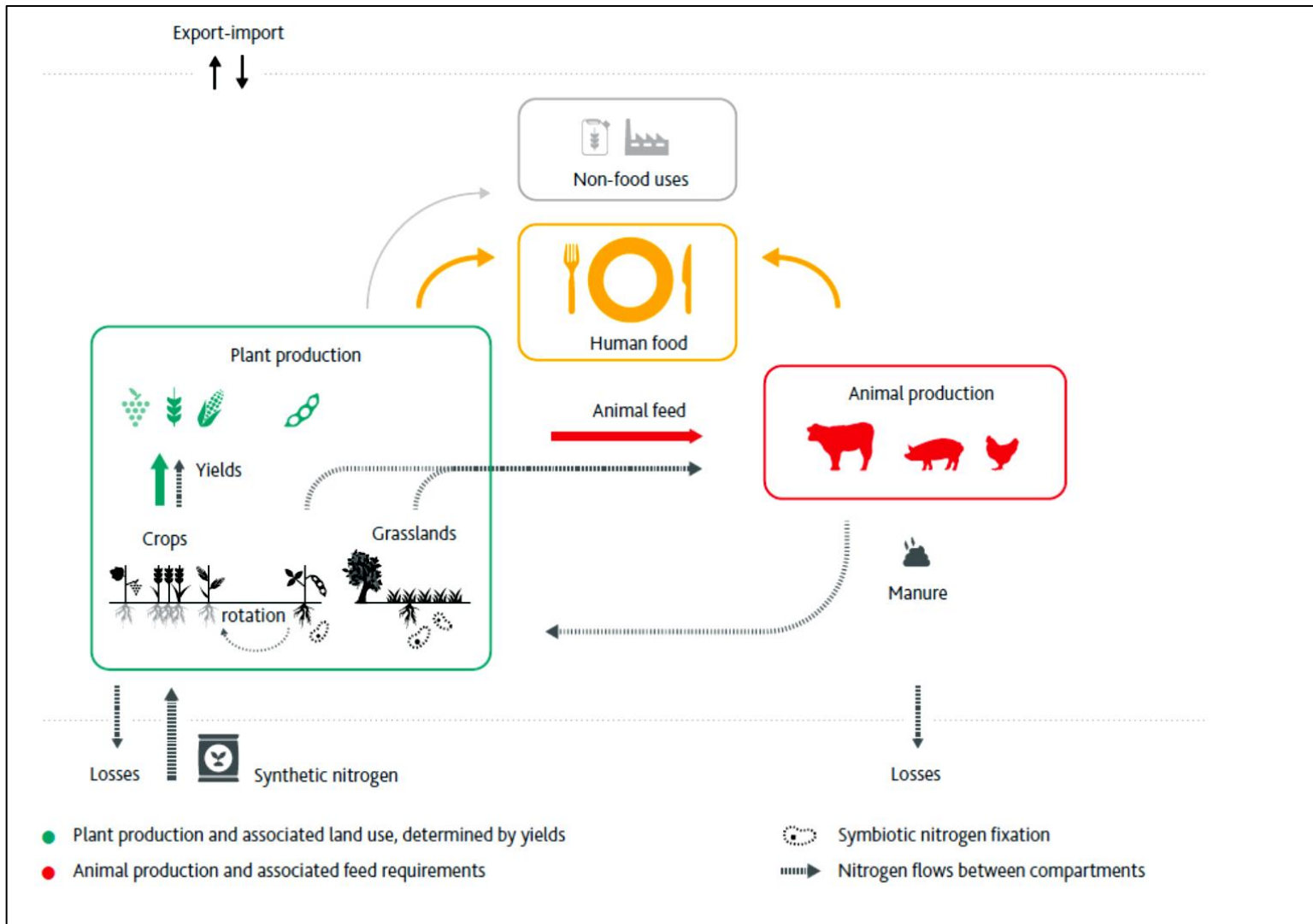
Food system efficiency perspective on soil (A) and crop (B) management as modifying factors of field-level interactions between soil (1), losses to atmosphere or water (2), nutrient inputs (3–6), and crop growth, leading to harvested products (7). www.sciencedirect.com.

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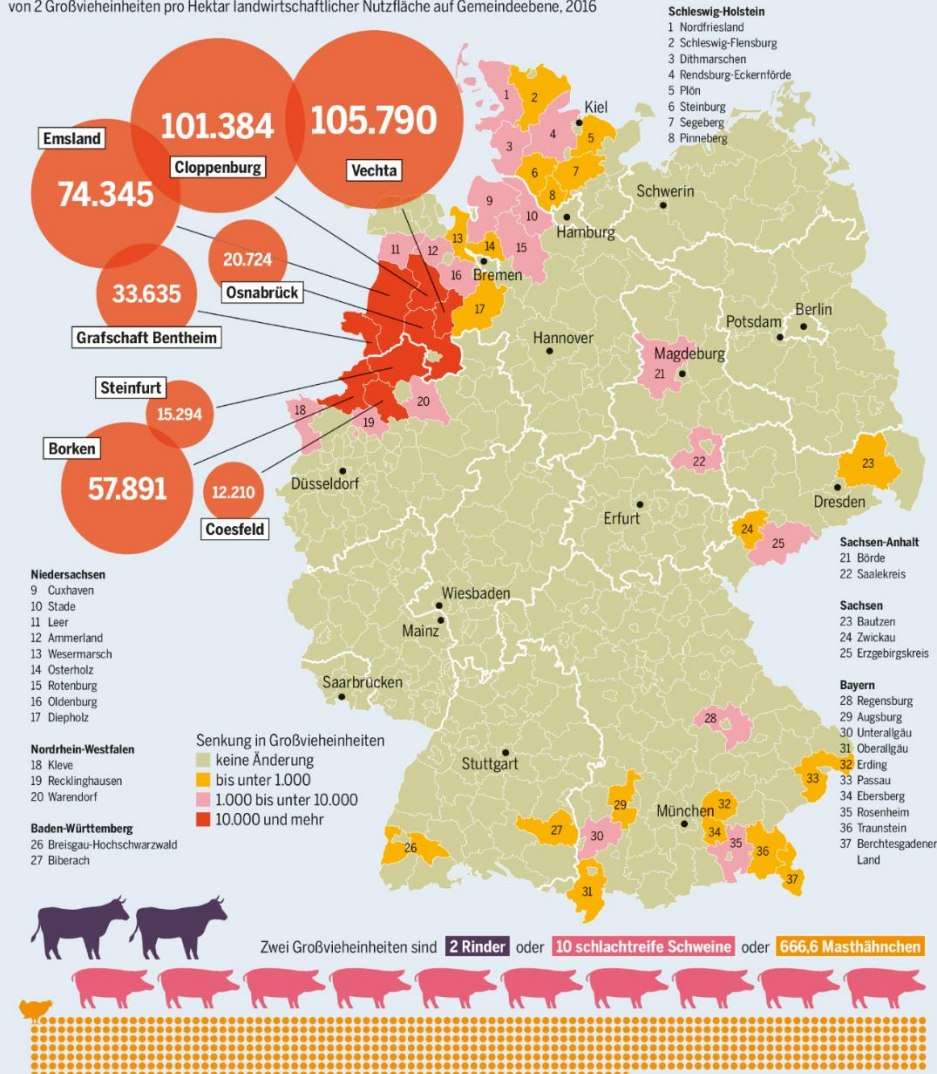
Spatial and temporal decoupling of animal husbandry from crop production (arable land and grassland)



Too many animals in a few places: Over-fertilisation, feed imports (LUC), stable sizes, animal welfare,...

AN WENIGEN STELLEN ZU VIELE TIERE

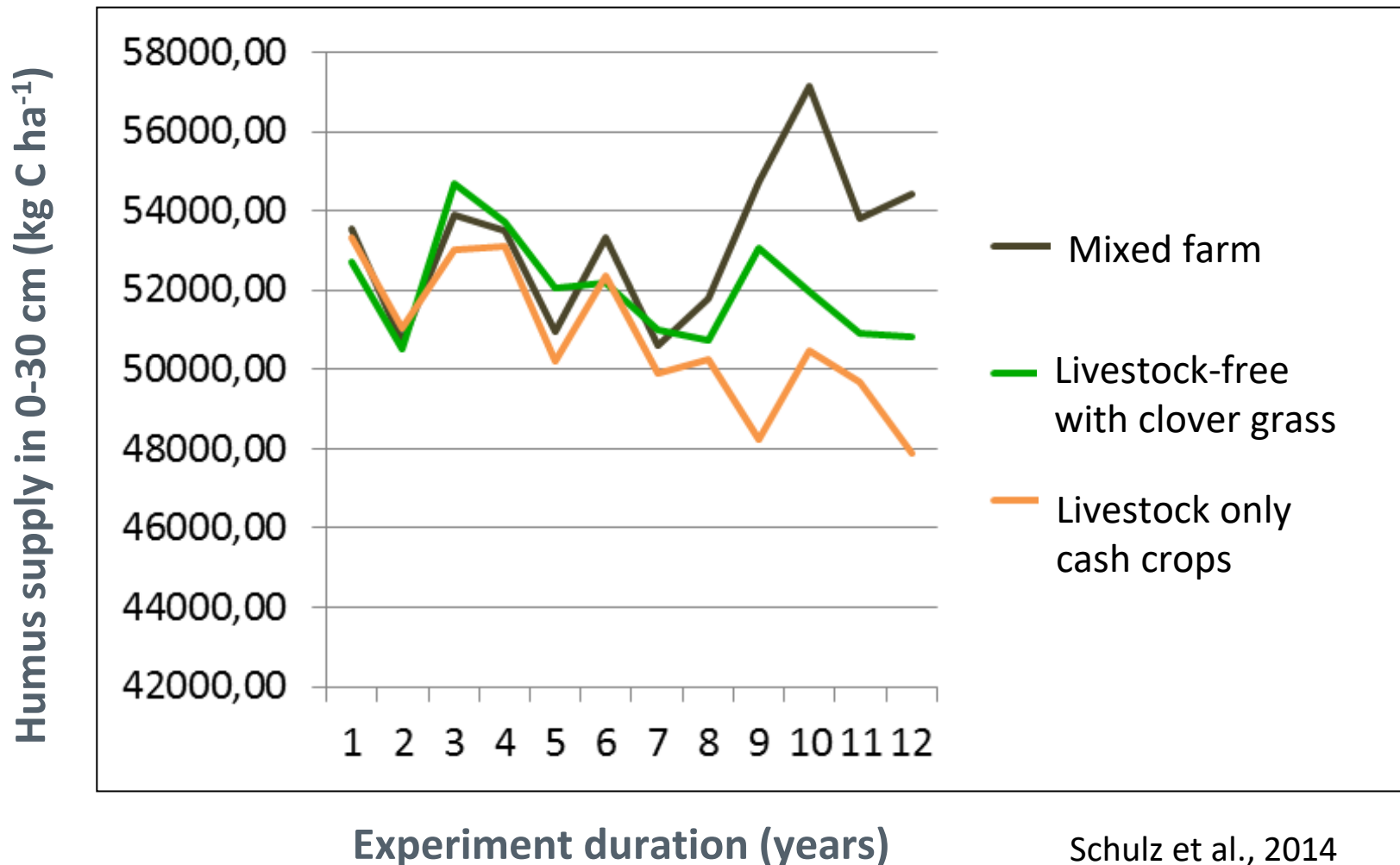
Abstockungsbedarf in Deutschland nach Landkreisen, Überschreitung der Besatzdichte von 2 Großvieheinheiten pro Hektar landwirtschaftlicher Nutzfläche auf Gemeindeebene, 2016



- Necessary reduction of livestock units (animal numbers) in the areas marked in yellow and red in order to achieve 2.0 LU/ha (= max. value for organic farming, EU Organic Regulation)
- Prescription by law of an area-based livestock farming system that is compatible with the natural environment?

Humus accumulation only on organic mixed farms with cattle husbandry

(Long-term Gladbacherhof OAFEG trial since 1998)



Schulz et al., 2014

Great nutrient potential through legumes and farm manure!



Global potential to produce 140 million tons of nitrogen on cropland
(Badgley et al., 2007)



Global potential to use 160 million tons of nitrogen (and other nutrients) from livestock manure more efficiently on cropland (calculated on the basis of 18.3 billion farm animals/FAO)

Low "carbon footprint" in grass-based milk production despite lower productivity compared to livestock housing!

Journal of Cleaner Production 211 (2019) 161–170

Contents lists available at ScienceDirect

Journal of Cleaner Production

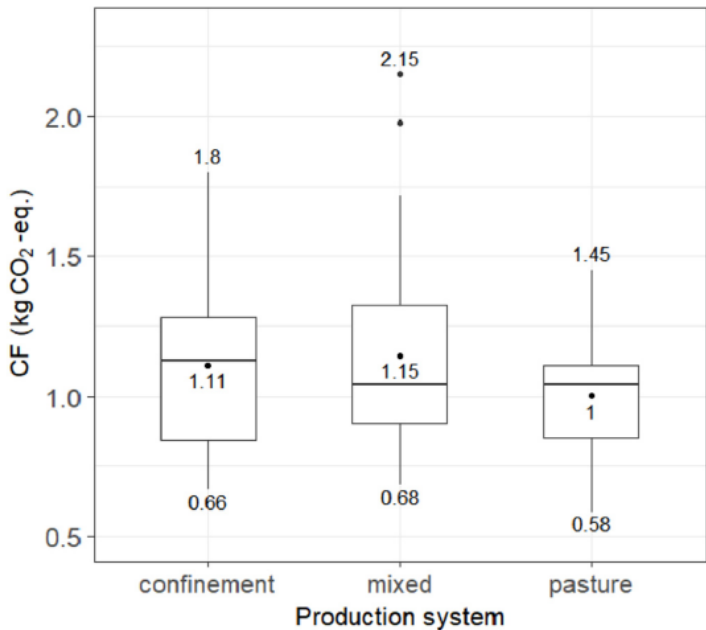
journal homepage: www.elsevier.com/locate/jclepro

Is low-input dairy farming more climate friendly? A meta-analysis of the carbon footprints of different production systems

Heike Lorenz ^{a,*}, Thorsten Reinsch ^a, Sebastian Hess ^b, Friedhelm Taube ^a

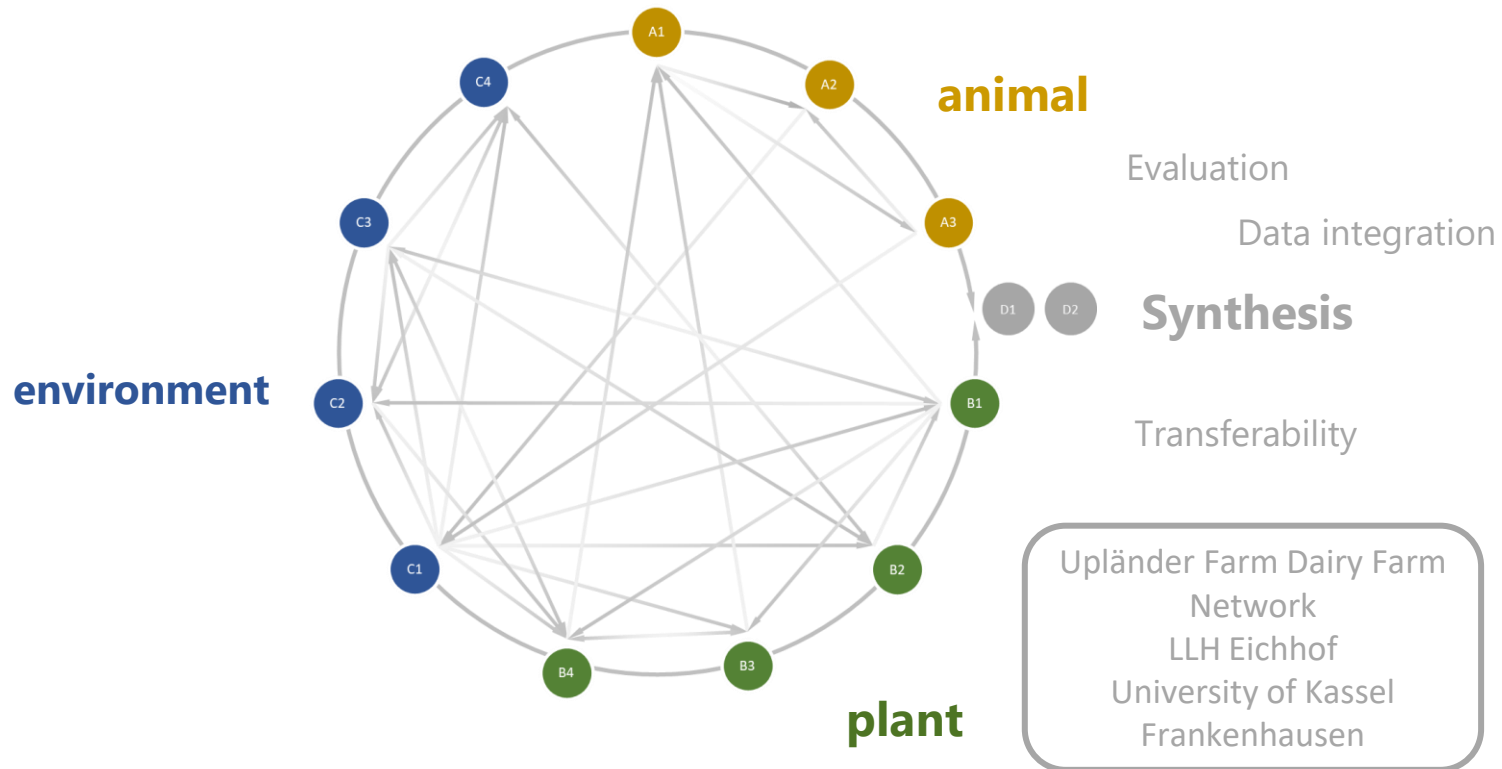
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GreenDairy: Goals

...to develop innovative, ecological crop-livestock systems that are both ecologically and economically sustainable, as well as enabling a special level of animal welfare, and thus enjoy a high level of acceptance in society.

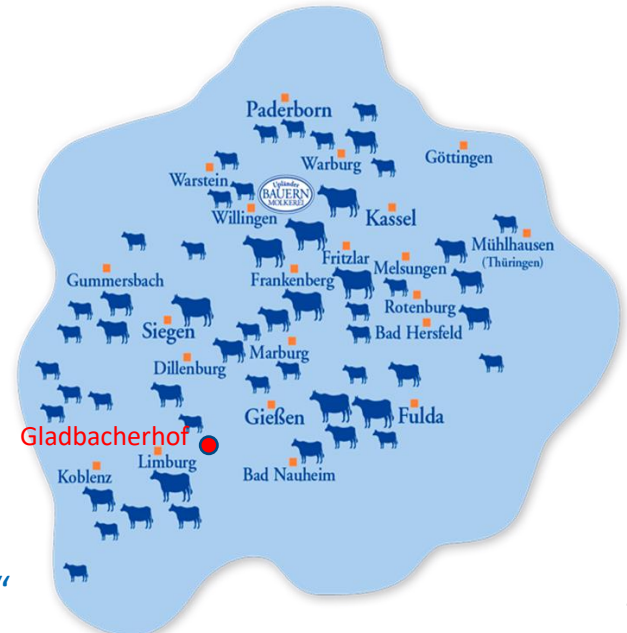
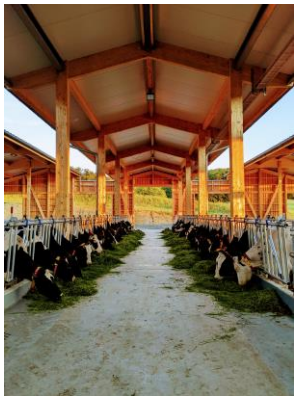




High-input: 9200 liters of milk/year, with corn silage in the diet
 Low-input: 7200 liters of milk/year, without corn silage in the diet

Crop rotation	High-input	Low-input
Year		
1	Alfalfa	Alfalfa
2	Alfalfa	Alfalfa
3	Winter wheat (human nutrition)	Winter rye (human nutrition)
4	Maize/sorghum millet (animal)	Potatoes (human nutrition)
5	Winter triticale (animal)	Winter wheat (human nutrition)
6	Grain legume (animal)	Grain legume (animal)
7	Winter spelt (human nutrition)	Winter spelt (human nutrition)
8	Spring oats (animal) + alfalfa as undersowing	Spring oats (animal) + alfalfa as undersowing

- Developing innovative crop-livestock systems, which are ecologically and economically sustainable at highest animal welfare levels and so they will be accepted by the society



...on the way to “Complex, multifunctional, organic agri-food systems, that will be sustainable and socially just and will be able to feed the world with significantly reduced greenhouse gas (GHG) emissions in 2050” (The Villum Experiment, 2016)



Cow Inge: *2008, 122.000 l life time performance, 12. lactation
Von 100.000 aktuell lebenden hessischen Kühen
nur etwa 20 mit dieser Leistung. Unter Bio Bedingungen in Deutschland
aktuell nur 5 lebende Kühe mit solch einer Leistung