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Lindhof

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# *Climate friendly low cost pasture based dairy production on a mixed farm in Northern Germany*

**Ralf Loges and Friedhelm Taube**

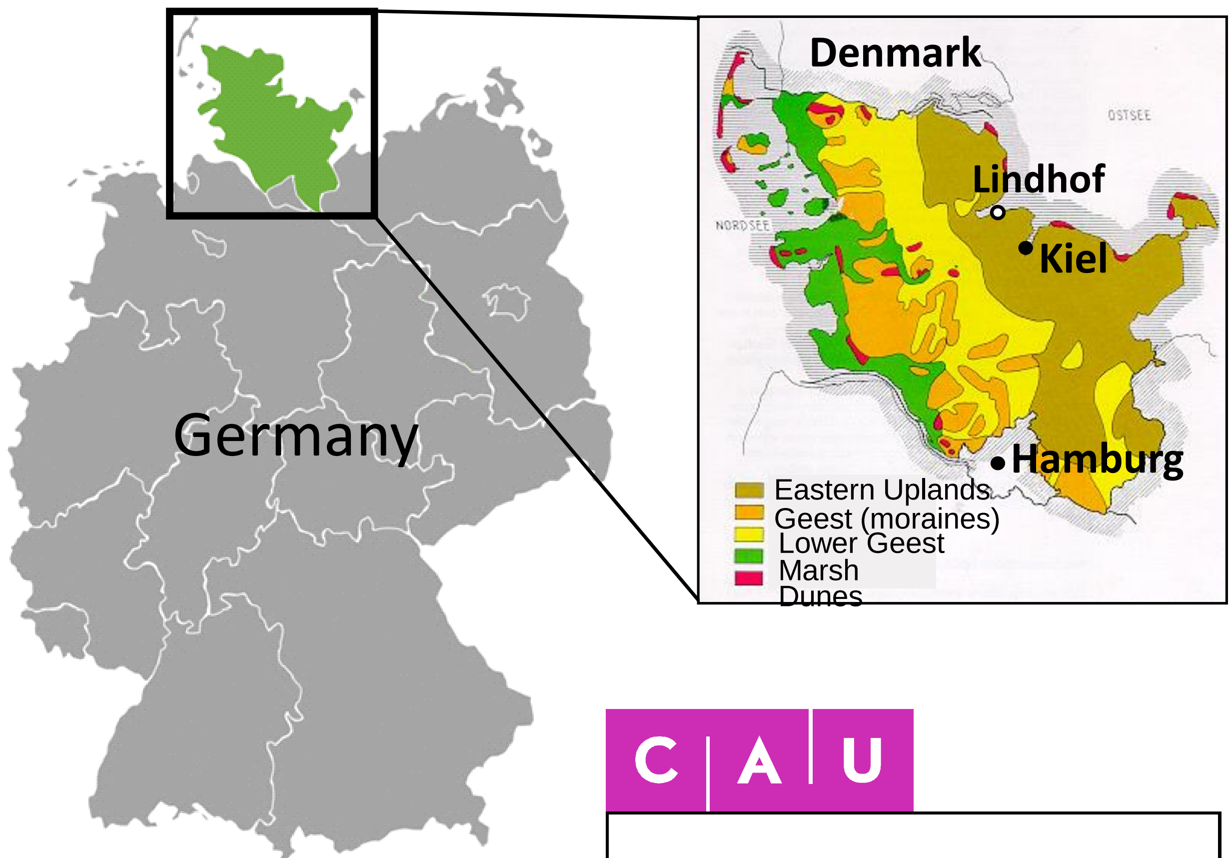
Grass and Forage Science/Organic Agriculture, University of Kiel, 24118 Kiel, Germany

European Commission

Resilience 4 for Dairy




# Dairy cows back to arable regions?
# Grazing leys for eco-efficient milk production systems




Dr. Ralf Loges
Institute of Crop Science and Plant Breeding
- Grass and Forage Science/ Organic Agriculture
+49 431 880-4654
rloges@gfo.uni-kiel.de

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

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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**

# 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**

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**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 sub-systems **and** consequently a lower demand for external resources
**Thus,** lower N- and $P_2O_5$ surpluses can be attained

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**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 $CO_2$sequestration in diversified crop rotations**

# And there is pressure from agricultural policy

**German Climate Protection Act 2021: Reduction of GHG by 65% by 2030, neutrality in 2045**
**German Agriculture: Reduction of GHG emissions to 56 million tons of $CO_2$eq**

**Farm to Fork Strategy: Aim: Making the European food system more sustainable**
**Implementation of Sustainable Development Goals/ SDGs:**
**Food security and sustainable production, by 2030 through:**

- **Reduction of chemical-synthetic pesticides by 50%**
- **Reduction of nutrient losses by at least 50%**
- **Reduction of fertilizer use by at least 20% while maintaining soil fertility**
- Reduction in the use of antibiotics in animal husbandry 50%
- Increase in organic farming to a share of 25%

**Implementation at national level of the following guidelines**

- **EU Nitrate Directive,**
- **European Water Framework Directive,**
- **EU Marine Strategy Framework Directive,**
- **EU Directive on National Emission Ceilings (NERC)**

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

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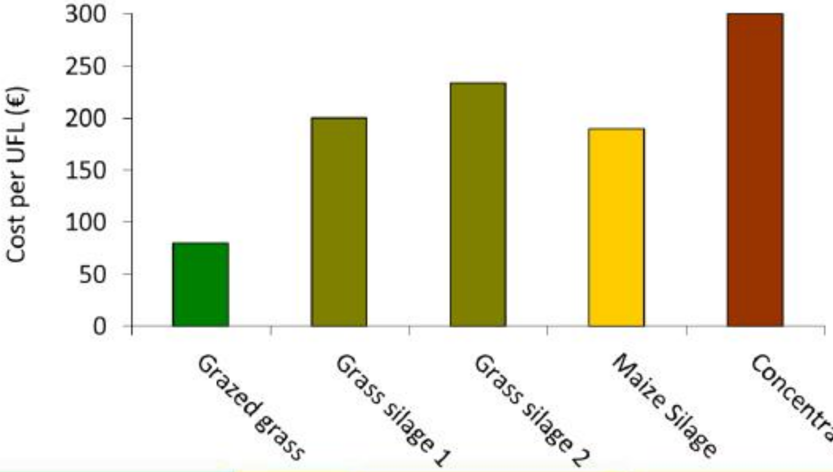
**Pasture is considered a cheap and environmentally friendly forage source** (Dillon et al. 2008, Rotz et al. 2009)




Humphreys, 2016

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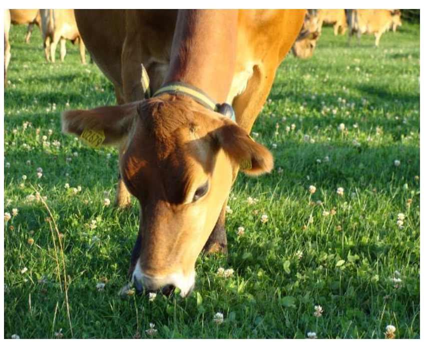



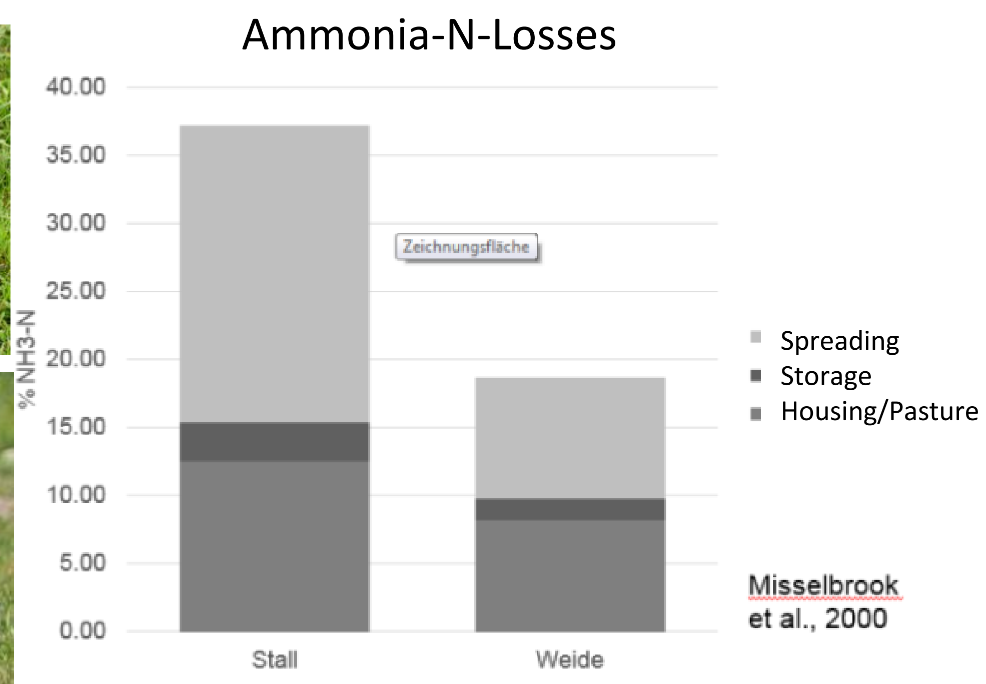

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**Pasture is considered a cheap and environmentally friendly forage source** (Dillon et al. 2008, Rotz et al. 2009)

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

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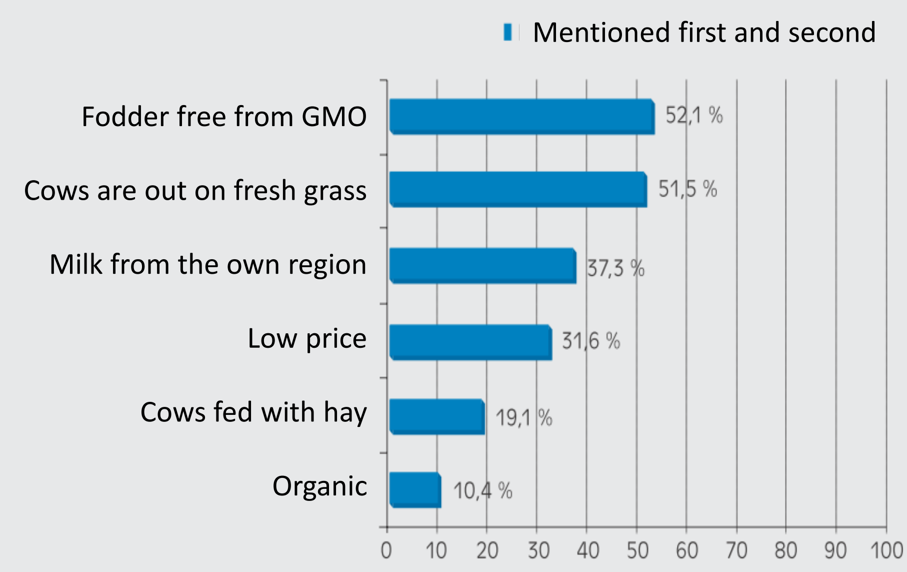


Ranking of most importand criteriaen when buying milk (Zühlsdorf et al. 2014)

# Background of the project “Eco-efficient pasture-based milk production”

**The interdisciplinary project: “Eco-efficient pasture-based milk production” started in 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**

# Experimental site and farm characteristics

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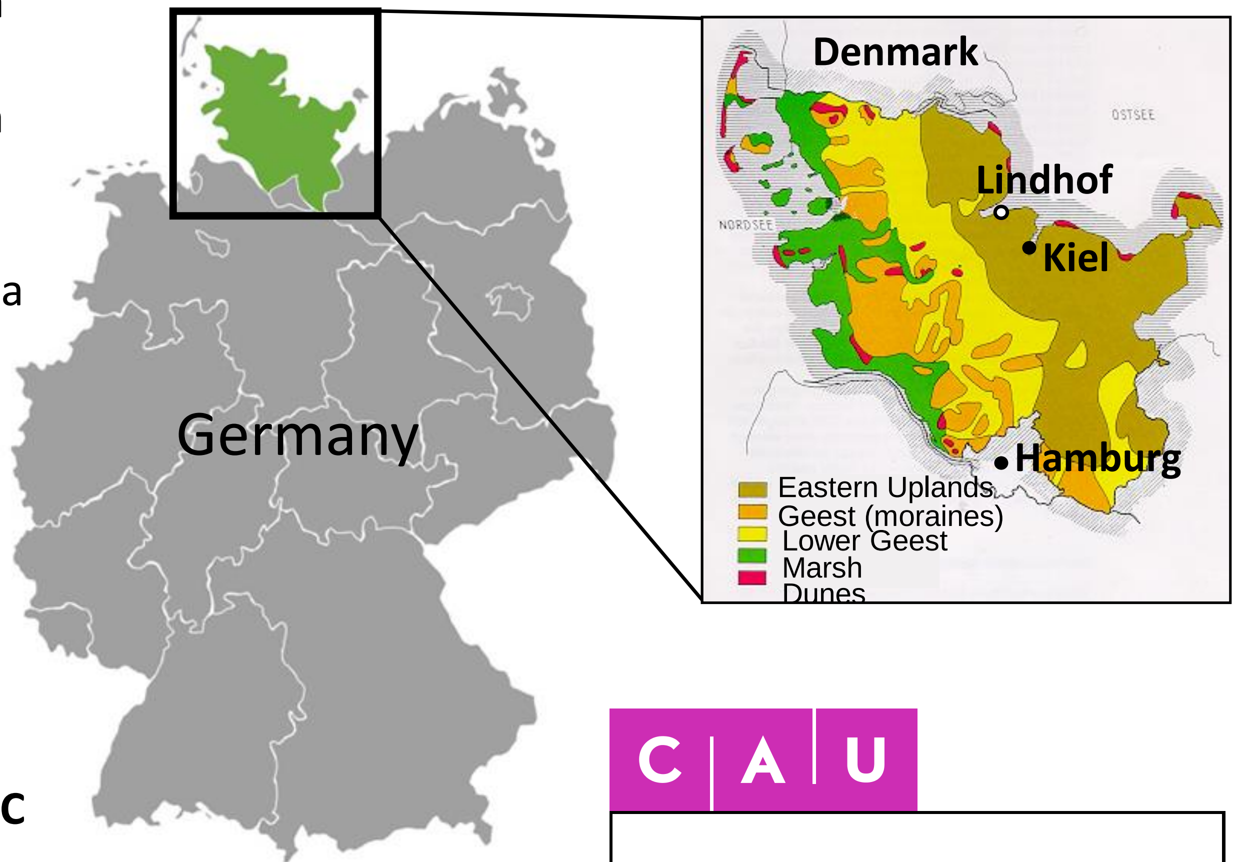
## Reintroduction of grazing for dairy cows on an organic mixed farm in Northern Germany

**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

**98 Dairy cows on 50 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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# “Eco-efficient milk production” Lindhof since 2016

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**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 ryegrass + white + red clover + birdsfoot trefoil + chicory + lancelot platain + carravay)

**Rotational grazing, after each milking allowance of fresh grass 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**

**Breed: Jerseys and Crossbreeds with EBI**

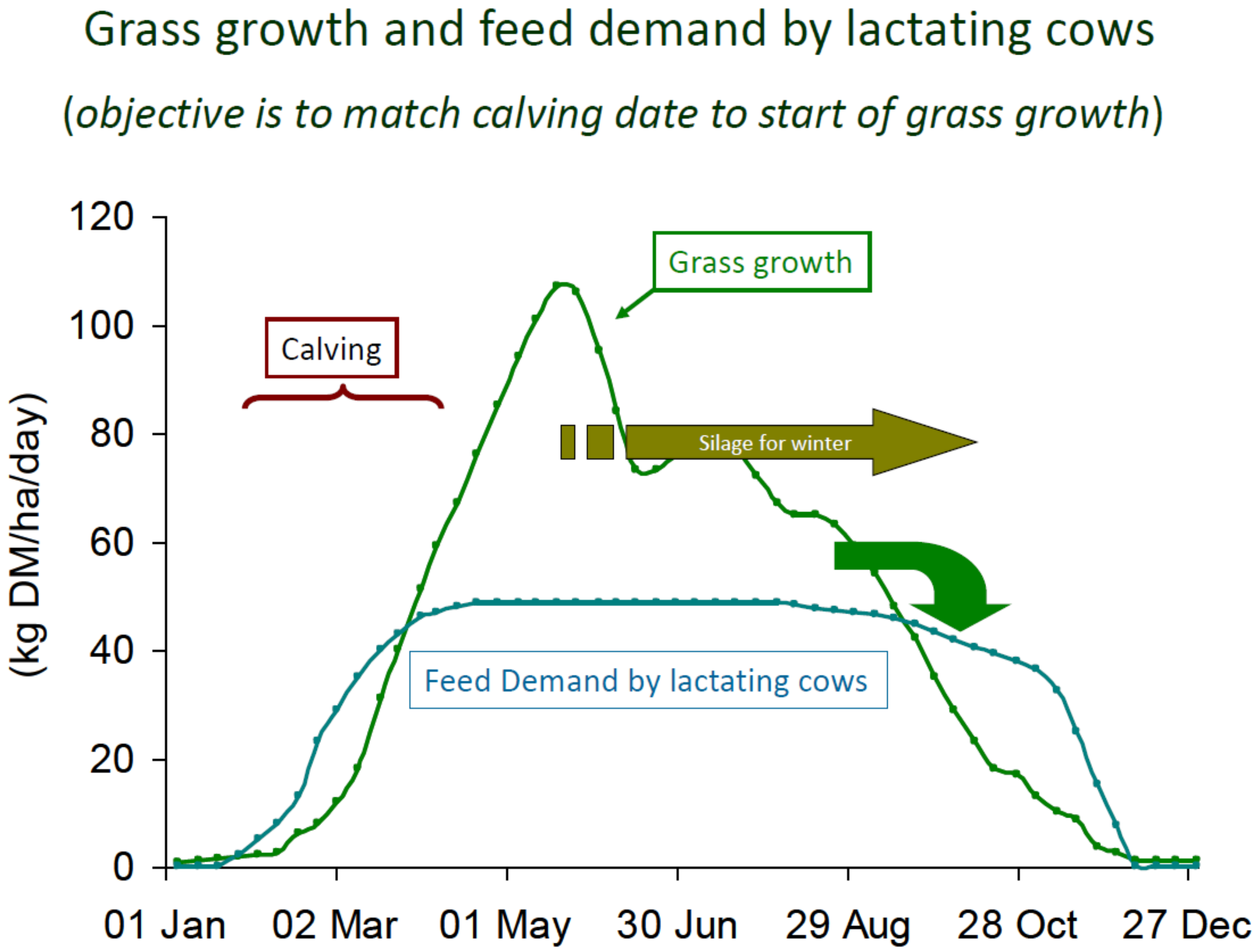
**First calving at an age younger than 24 month**

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

**Selfsufficiant with concentrates** (Triticale + Faba beans)

# Inspiration came from Ireland

## We tried to transfer the Irish sytem to Northern Germany




Humphreys, 2016

# Comparison of grass growth between Lindhof and Ireland



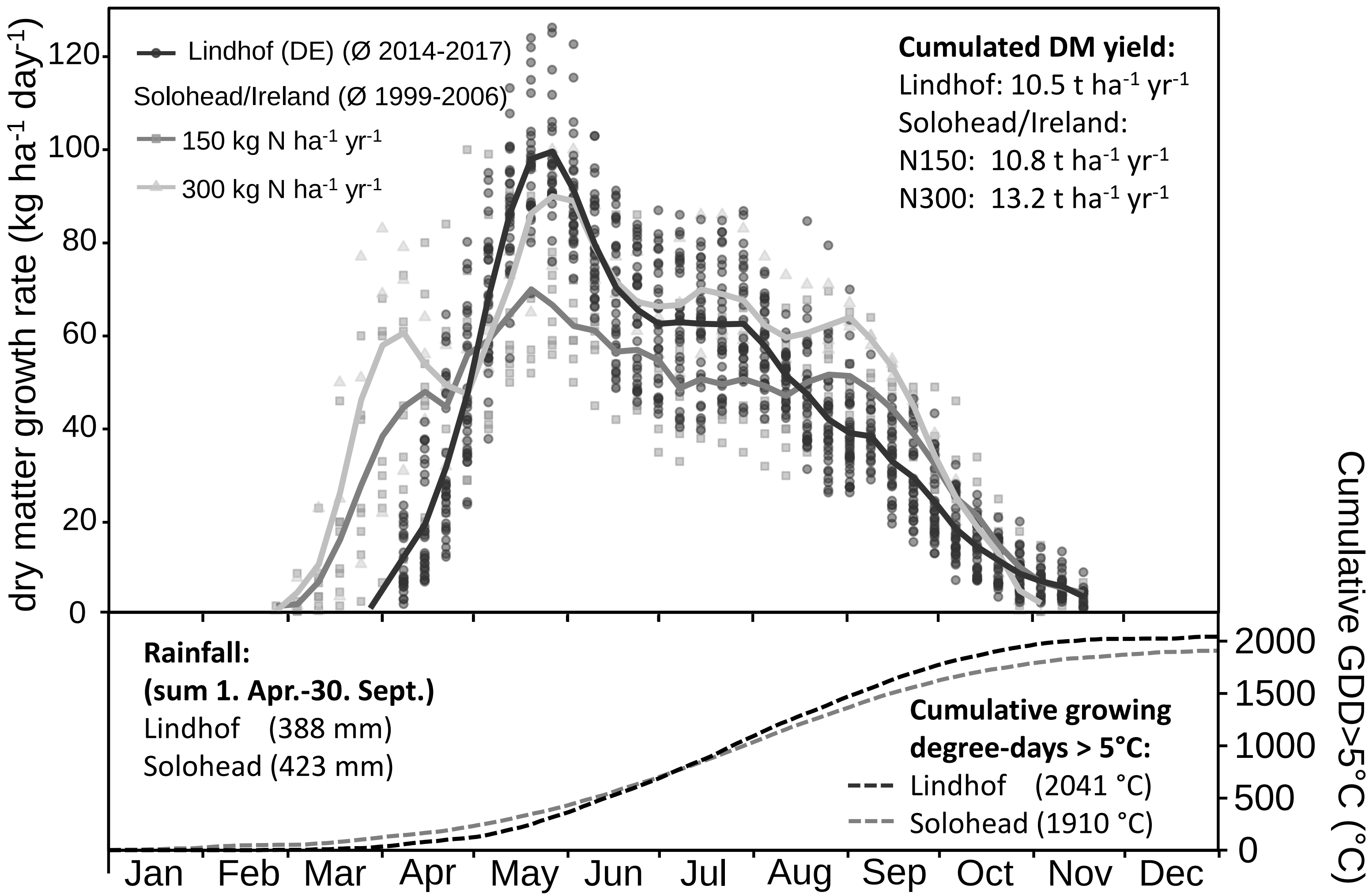
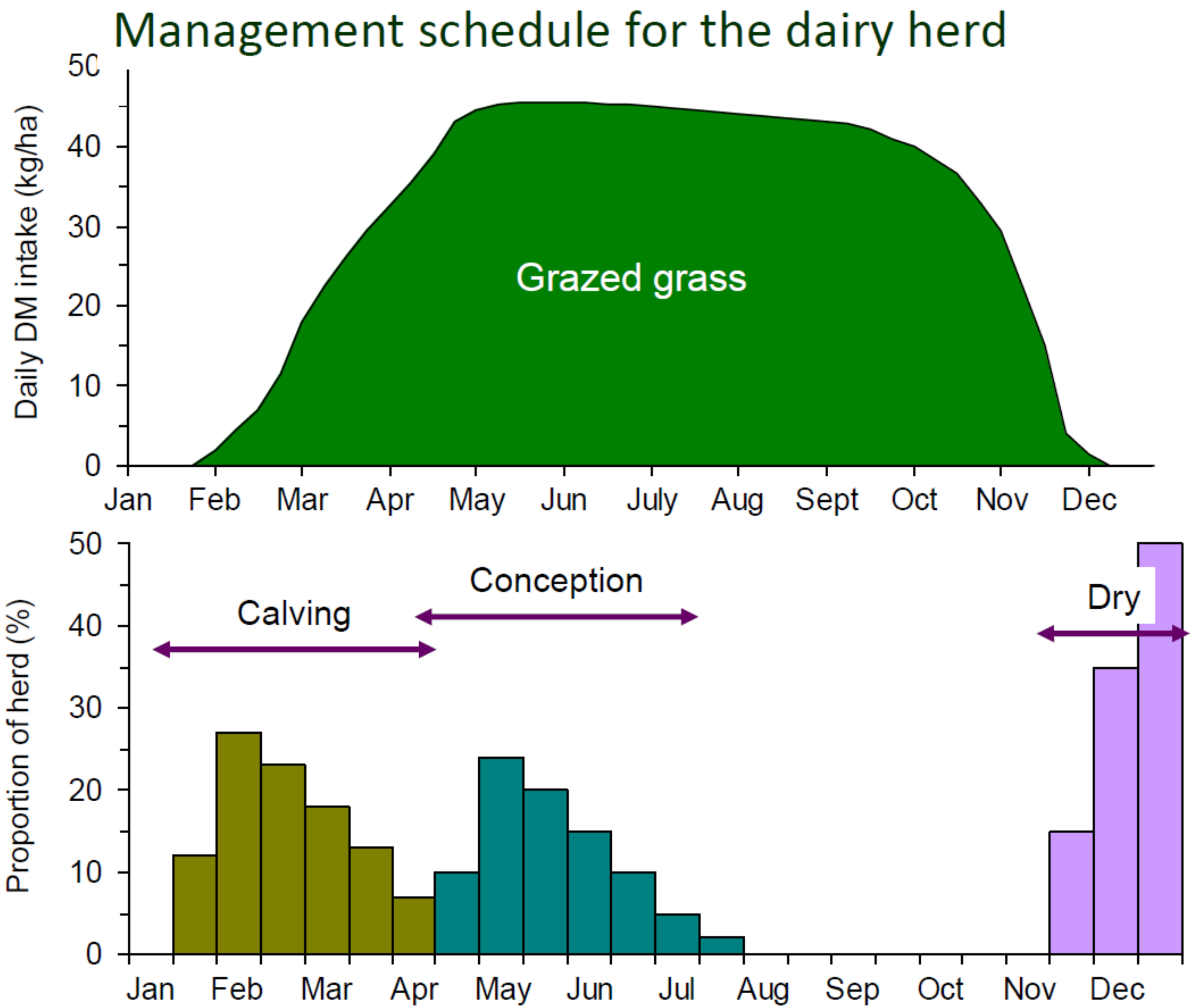



Figure 1. a) Daily growth rates (kg DM ha$^{-1}$) for grass clover without inorganic N fertiliser at Lindhof (2014-2017) compared to daily growth rates measured at Solohead (1999-2006) of grassland fertilised with 150 kg N ha$^{-1}$ yr$^{-1}$ and 300 kg N ha$^{-1}$ yr$^{-1}$ respectively, b) cumulated growing degree-days >5°C at Lindhof (2014-17) compared to Solohead (1999-2006).

# Inspiration from Ireland

## The ”Irish sytem” (Humphreys, 2016)



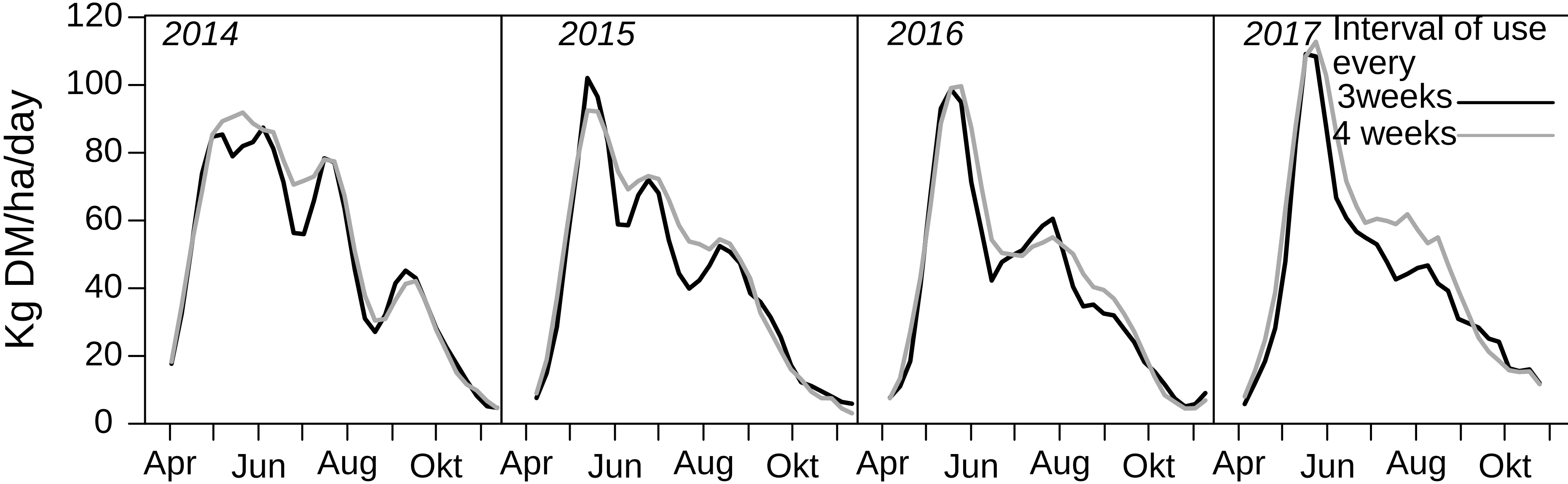
# Growth of organic grass clover at Lindhof

# in 2 different grazing intervals

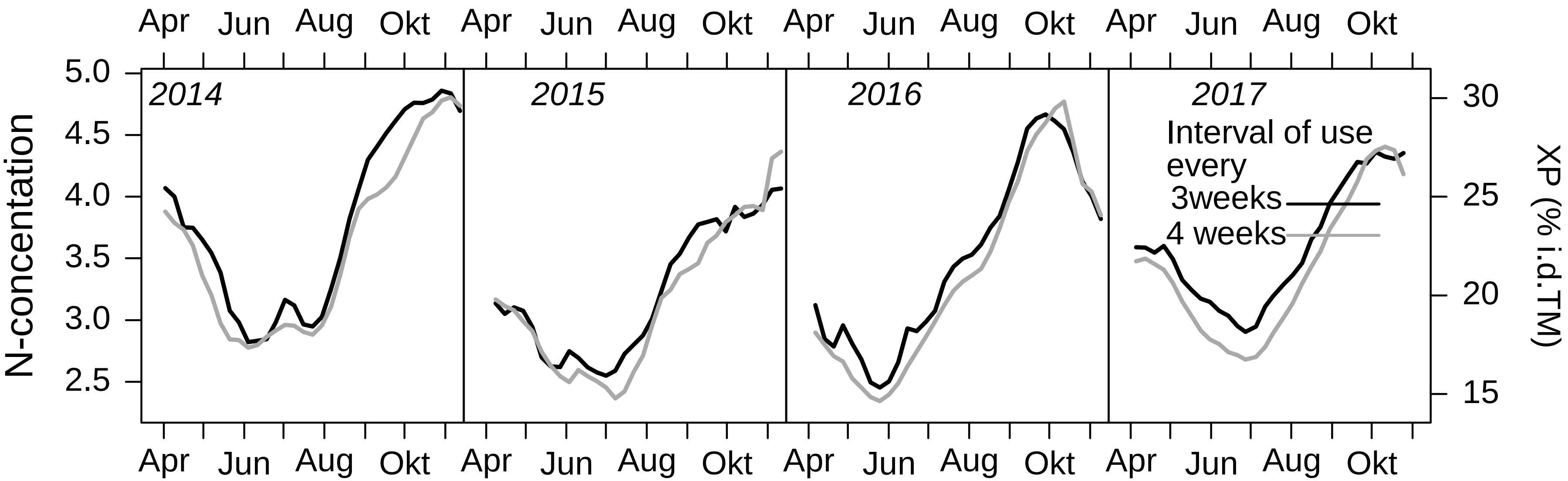
(Average yearly rainfall: 785mm

Average temperature 8,7°C)

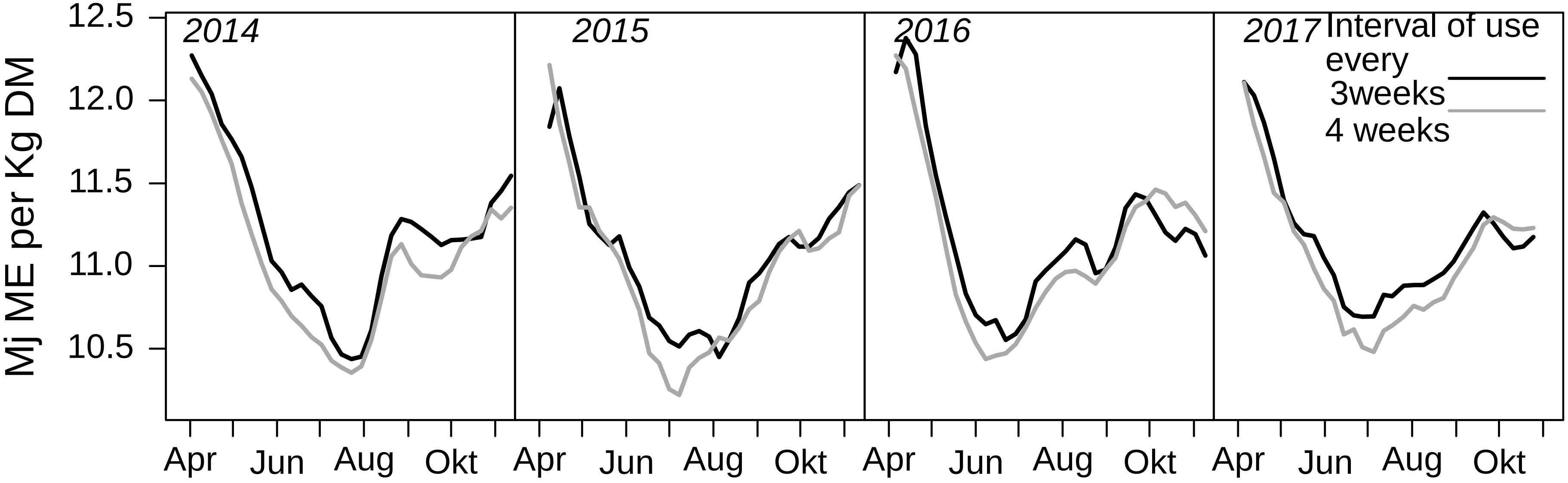
On sandy loamy soils



# Change in crude –protein-concentrations of organic grass clover at Lindhof in 2 different grazing intervals



**Change in concentration of metabolizable energy of organic grass clover at Lindhof in 2 different grazing intervals**



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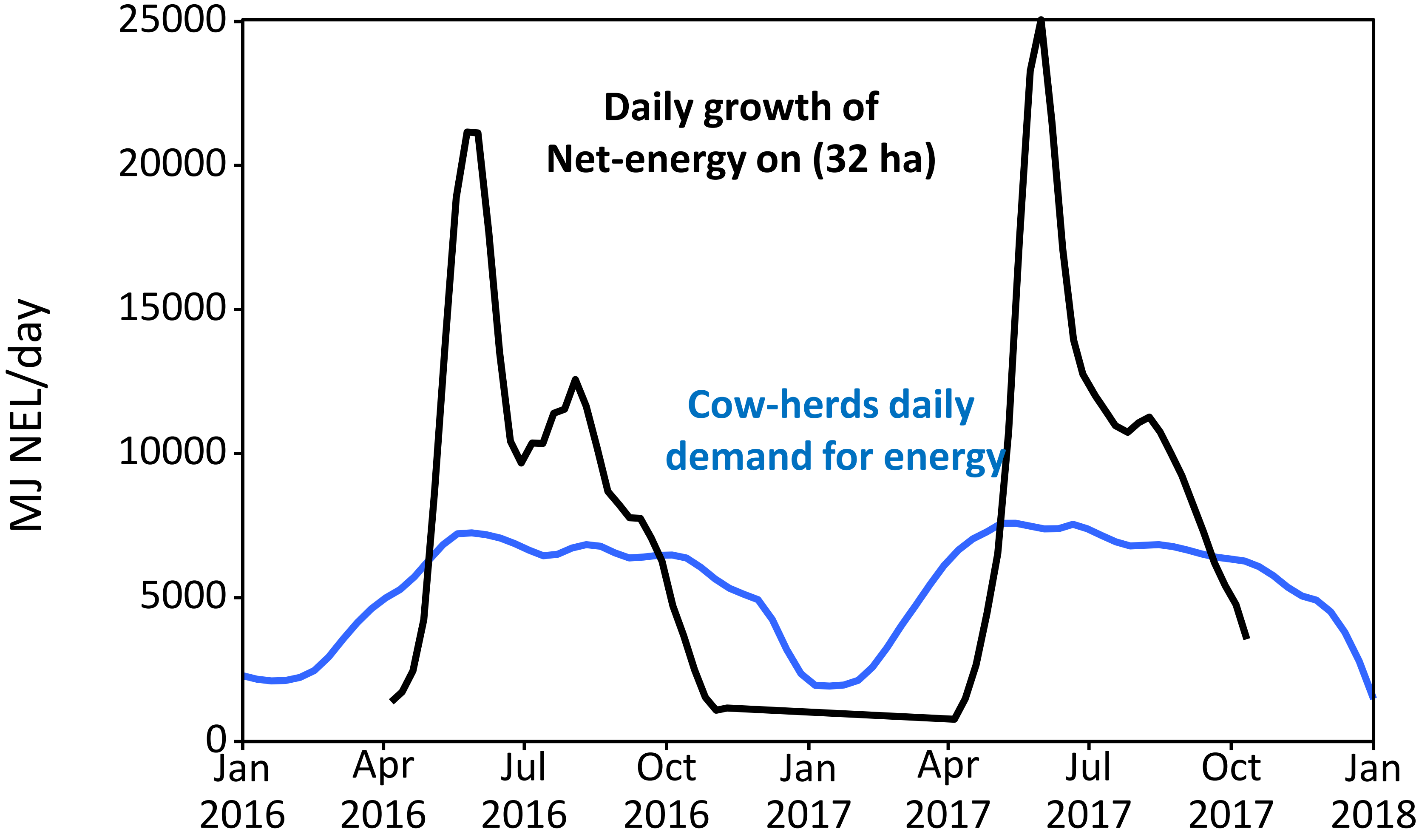
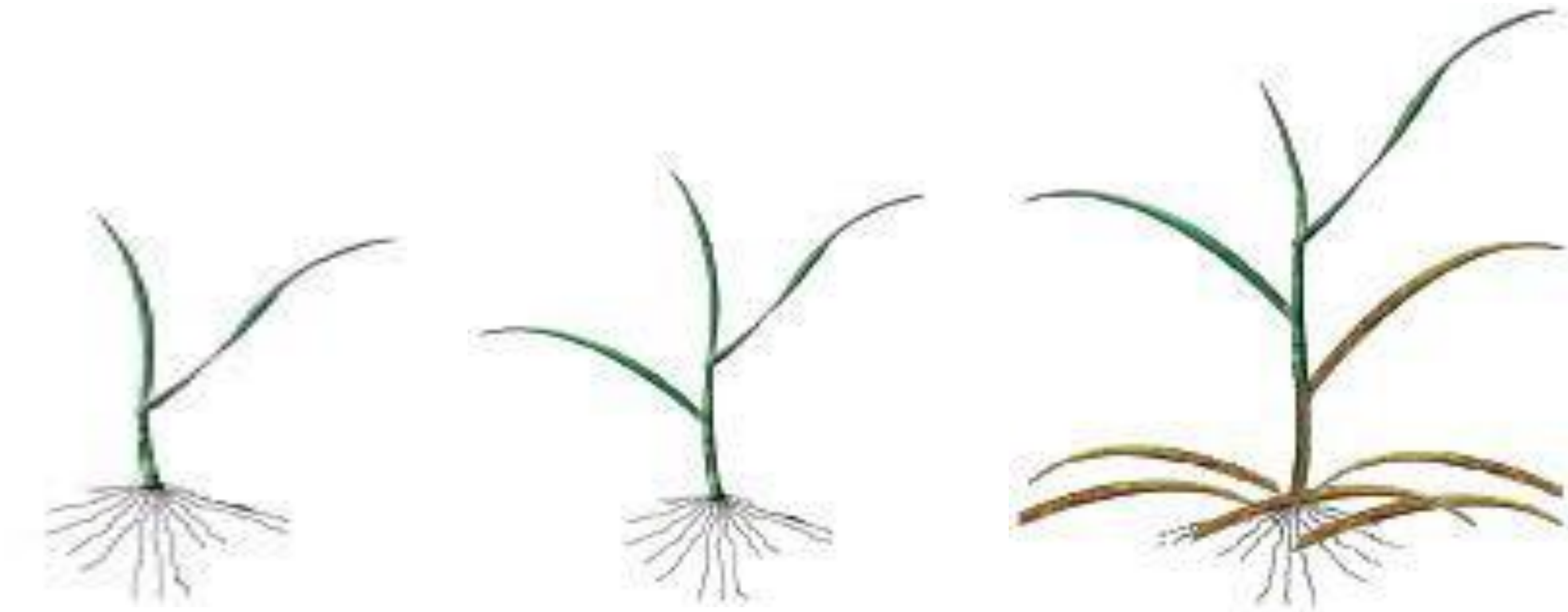
- Syncronisation between the cows daily energy demand and Daily growth of Net-energy (the first 2 years of experience)



# Grazing around the 3 leaf stage

**≤ 2 leaf** | **2.5 - 3 leaf** | **> 3 leaf**



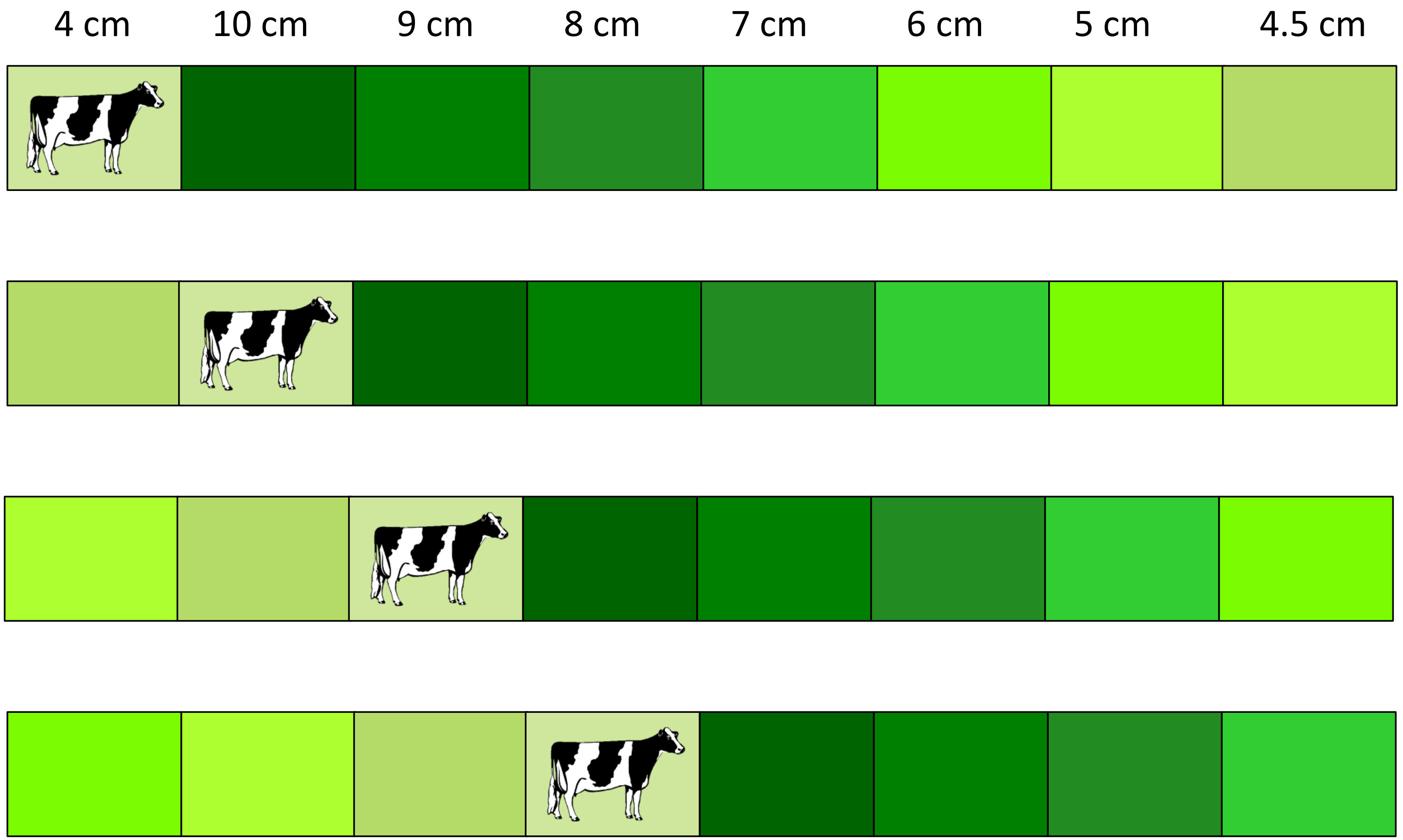
**Sub optimal yield potential**

**Optimal energy-yields**

**Decreasing forage quality**

Source: Schleip et al., 2011

# Rotational grazing at Lindhof, fresh grass after each milking

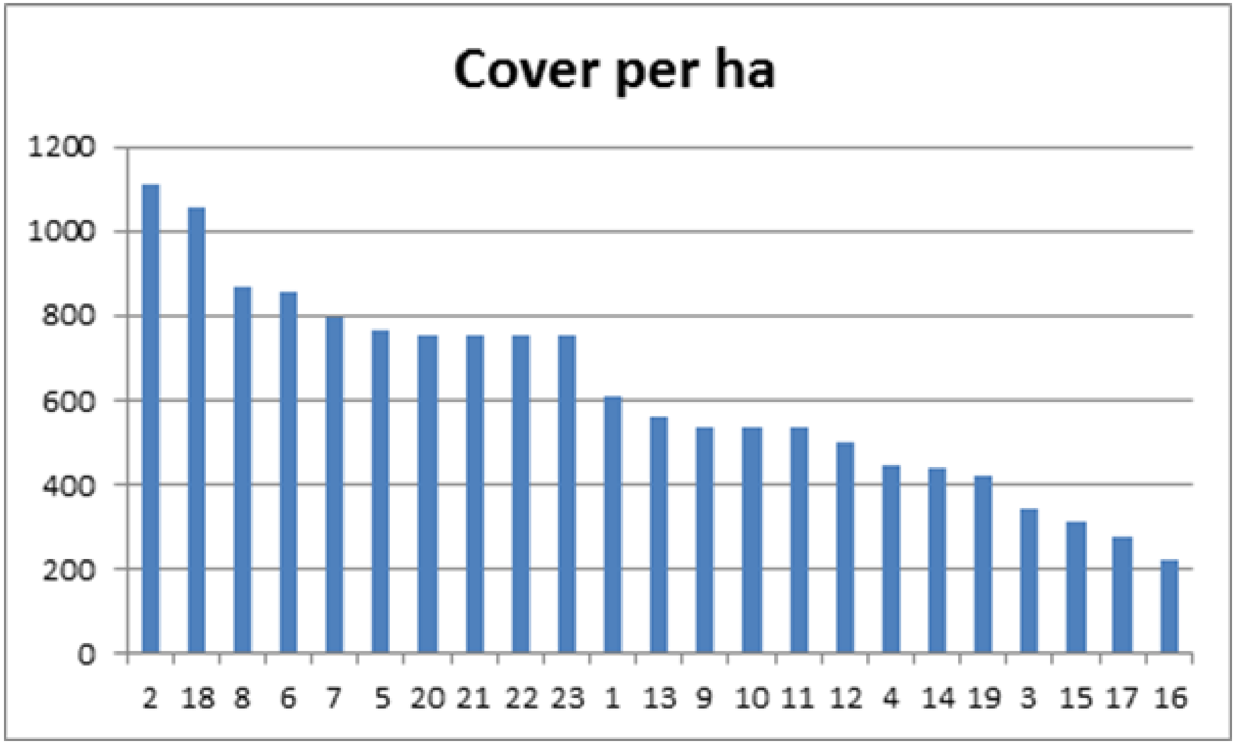


# Rising platemeter as central tool for optimisation of grazing

**- Rotational grazing, after each milking allowance of fresh grass based on platemeter readings**

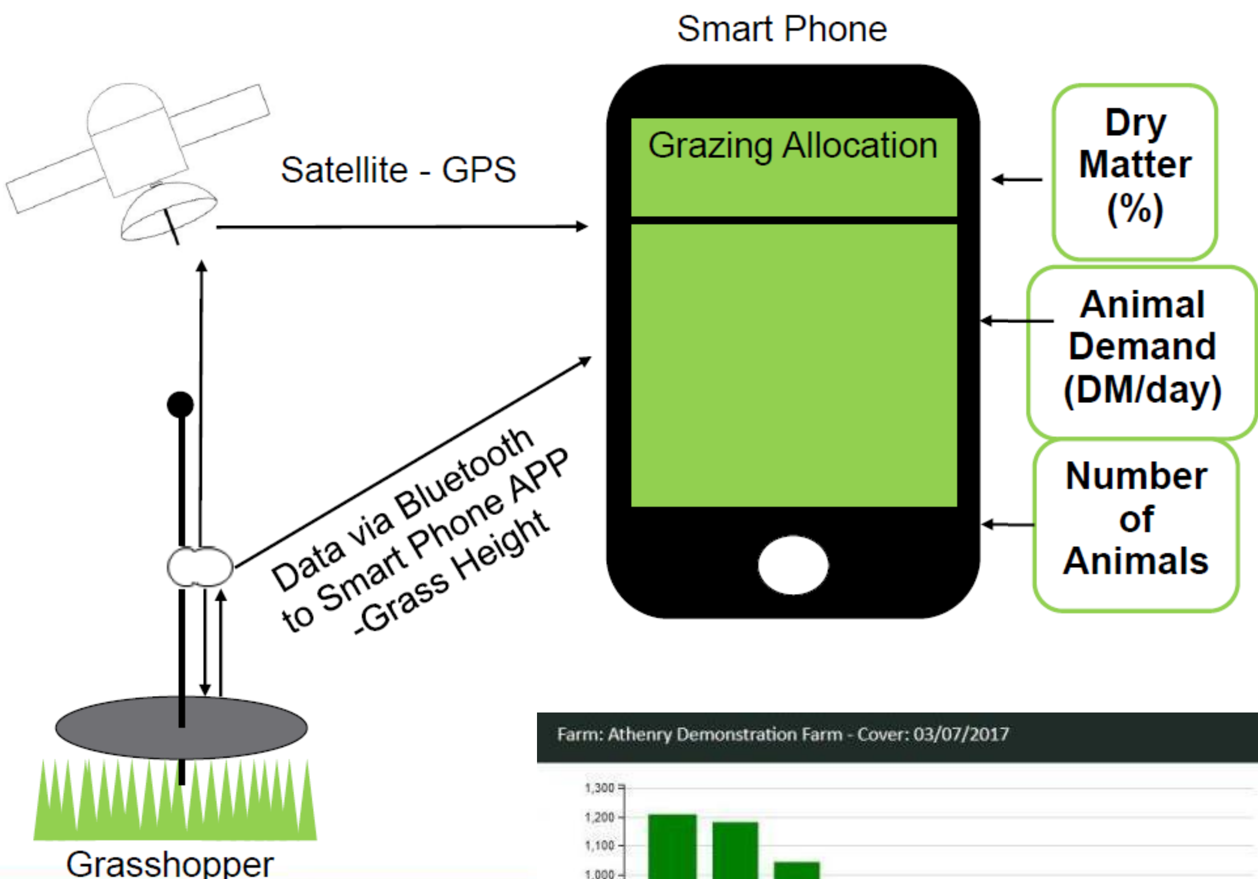
# Feed wedge baseret on rising platemeter readings

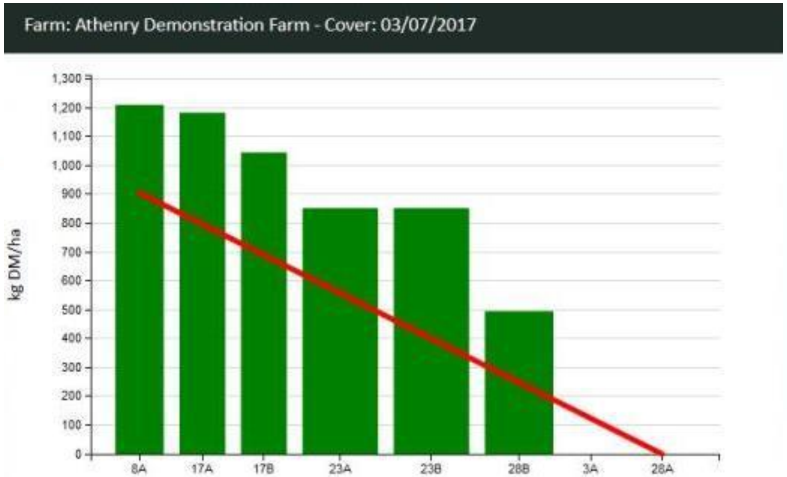
**- Silage cuts are under taken when the grass gets to long**



# We also use digital rising plate meters e.g. the grasshopper

**Also borrowed from Ireland**

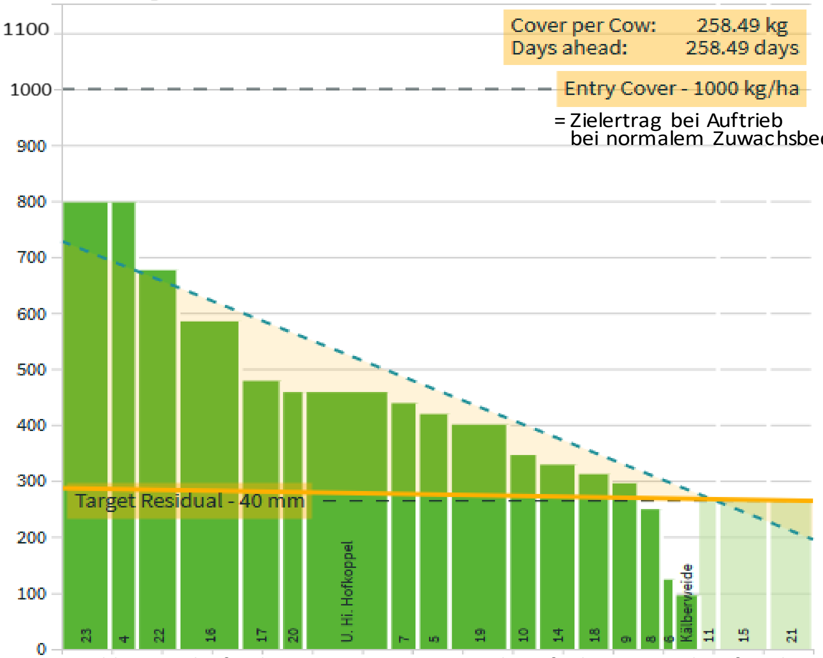




**Anzeige auf dem Handydisplay:**
**19 von 20 Messpunkten sind erfasst**

# Verfügbarer Weideaufwuchs je Schlag




Schläge mit laufender Nummer sortiert nach verfügbarem Weideaufwuchs

Demand Line = Bedarf, hier für 10 Std. Halbtagsweide (Trockenheits-bedingt)

Average Cover = durchschnittlicher Aufwuchs (verfügbar)

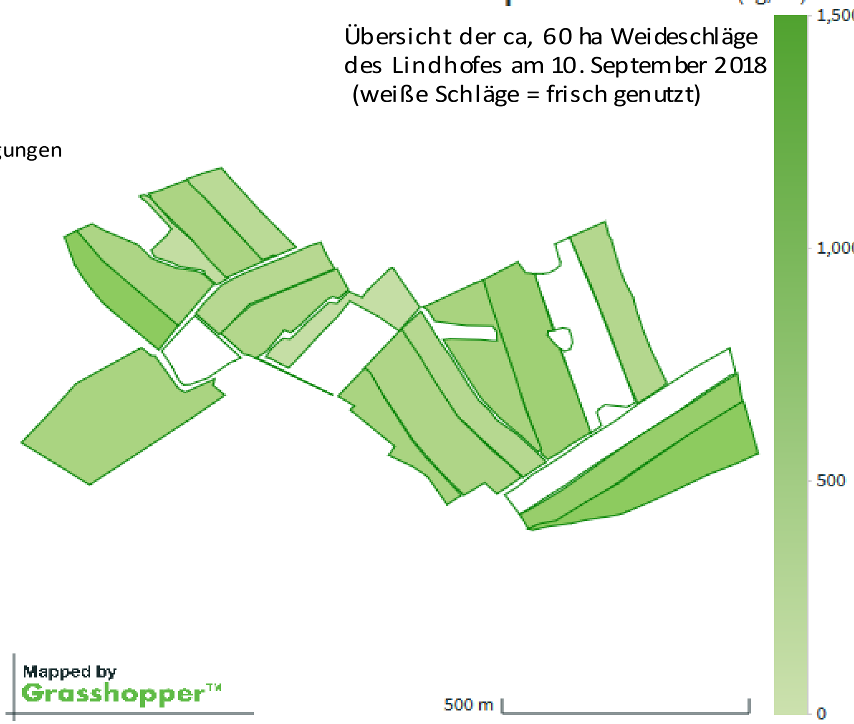
Rotation length (days) = hier 15 Tage (wegen noch Trockenheits-bedingt verhaltenem Nachwuchs)

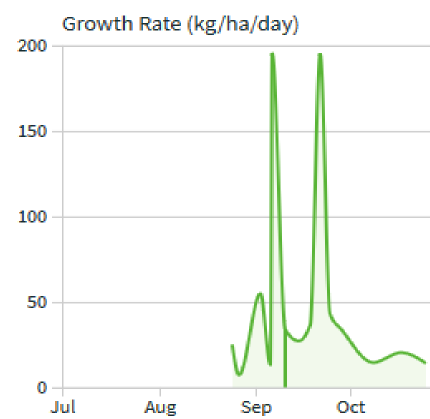
<< **September 2018** >>

| Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|---|---|---|---|---|---|---|
| | | | | | | 1 |
| 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| 30 | | | | | | |

## Schlag-Karte

Übersicht der ca, 60 ha Weideschläge des Lindhofes am 10. September 2018 (weiße Schläge = frisch genutzt)




## Farm Metrics

| | |
|---|---|
| Current Total Farm Cover | 9670kg |
| Display-Group Cover | 10890kg |
| Total Daily Requirement | 8kg |
| Daily Growth | 1058kg (33.84kg/ha) |
| Year to Date Growth | 9702.38kg (183.77kg/ha) |

# “Öko-effiziente Weidemilcherzeugung” Lindhof



Getting the calved cows out as early as we can (early March). In early spring net energy-concentration of grass is high, cows find more grass as we had expected
Early Grazing is supporting tillering and sward density

# “Eco-efficient milk production ” Lindhof

Christian-Albrechts-Universität zu Kiel

Integration of deepr rooting red clover and forage herbs into the grazed leys

# Eco-efficient milk production ” Lindhof

Christian-Albrechts-Universität zu Kiel

Co-operation with an organic all-arable farm (Aaf) (Win-Win –situation)
Exchange of Farm-yard manure to grass clover (1st and 2nd cut silage) since 2020
Faba Beans and Corn from Aaf exchanged with winter wheat produced at Lindhof

# “Eco-efficient milk production ” Lindhof

Christian-Albrechts-Universität zu Kiel

2018 Cross breeding Jersey x Irish Black and White (EBI)

# “Eco-efficient milk production ” Lindhof



Since 2020 Rotational crossbreeding based on three breeds

Jersey x Irish Black and white (EBI) x Angler (in family with Scandinavian Red)

# “Eco-efficient milk production ” Lindhof

Christian-Albrechts-Universität zu Kiel

27th of Nov.2018

20th ofSept.2018


Autumn Grazing of grass grown as catch crops
(Annual ryegrass receiving thin summer slurry)
and of Grass-Clover-Unterstoreys established in winter cereals

# Rising platemeter as central tool for optimisation of grazing

**Some adjustments over time:**
**Paddock size has increased, multi access points, movable water troughs give more flexibility in accurate forage allowance**
**Grazing clover rich fields during late summer and autumn is challenging**
**We then decrease grazing height to decrease the risk of tympani**

# Results

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 of Schleswig-Holstein
(These farms feed mainly all year indoor and keep mainly “Holstein Frisians”, but also “Red Holstein Dual Purpose” and “Angeln Cattle” a small minority are organic farmers)
(Branch accounting of milk production (BZA) source: LK-SH (2021))

Abbreviations:
SH = Schleswig-Holstein,
ECM = energy-corrected milk,
MFA = main forage area,
BZA = branch accounting,

# Results

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**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 of Schleswig-Holstein (Branch accounting of milk production (BZA))

| | Unit | Lindhof | Average of 356 by 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 plus protein) | kg $cow^{-1}$ | 592 | 702 |
| Fat | % | 5.59 | 4.2 |
| Protein | % | 3.99 | 3.45 |
| Concentrate feeding | dt $cow^{-1}$ $year^{-1}$ | 8.00 | 28.10 |
| 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] | % | 75.41 | 39.93 |
| Adjusted reproduction rate | % | 18.20 | 33.40 |
| First calving age (LKV-SH, 2021) | months | 24.6 | 28.4[e] |
| Calving interval (LKV-SH, 2021) | days | 362 | 400[e] |
| Costs for veterinary, medicines + hoof care | ct $kg^{-1}$ ECM | 1.48 | 1.64 |
| Total feed costs[d] | ct $kg^{-1}$ ECM | 16.81 | 22.12 |
| Costs of producing forage | ct $kg^{-1}$ ECM | 12.17 | 13.35 |
| Concentrated feed costs | ct $kg^{-1}$ ECM | 3.83[g] | 8.77 |
| Mineral N fertilizer input | kg N $ha^{-1}$ MFA | 0 | 99 |
| N balance MFA [f] | kg N $ha^{-1}$ MFA | 88 | 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 region, [f] Farm-gate N balance of only the dairy operation, [g] from organic production at a 63% higher price

# Results

**Table 2**: Nitrogen balance (2019/20) experimental farm Lindhof

| | **Unit** | **Lindhof** | **Average of 356 by BZA** |
|---|---|---|---|
| Mineral N fertilizer input | kg N $ha^{-1}$ MFA | 0 | |
| N-surplus forage area (55 ha) | kg N $ha^{-1}$ MFA | 88 | |
| N- export to cash crops (56 ha) | kg N $ha^{-1}$ MFA | 60 | |
| N-surplus forage + cash crop area (111 ha) | kg N $ha^{-1}$ MFA | 18 | |

# Results

**Table 3**: Full costs analysis of forages in the 2019/2020 financial year

| | **Lindhof Pasture with 1-2 silage cuts on grass-clover** | **BZA 2019/20* grass-silage** | **BZA 2019/20* 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, € $ha^{-1}$ | 943.75 | 1,865.98* | 2,039.44* |
| 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

# 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**


# Materials and Methods Environmental parameters

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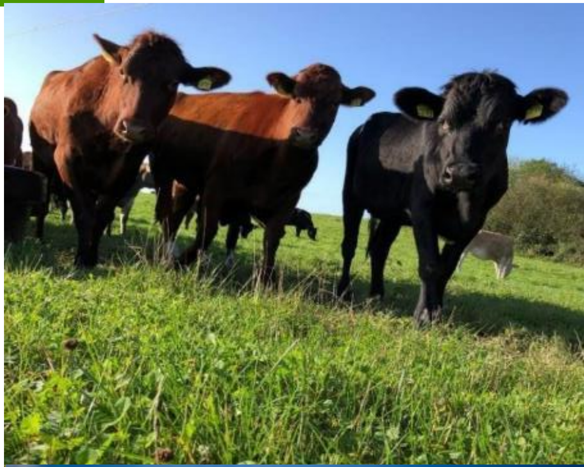


**Forage yield was determined using a rising plate meter and hand sampling**

**Forage quality was estimated using NIR-spectroscopy.**

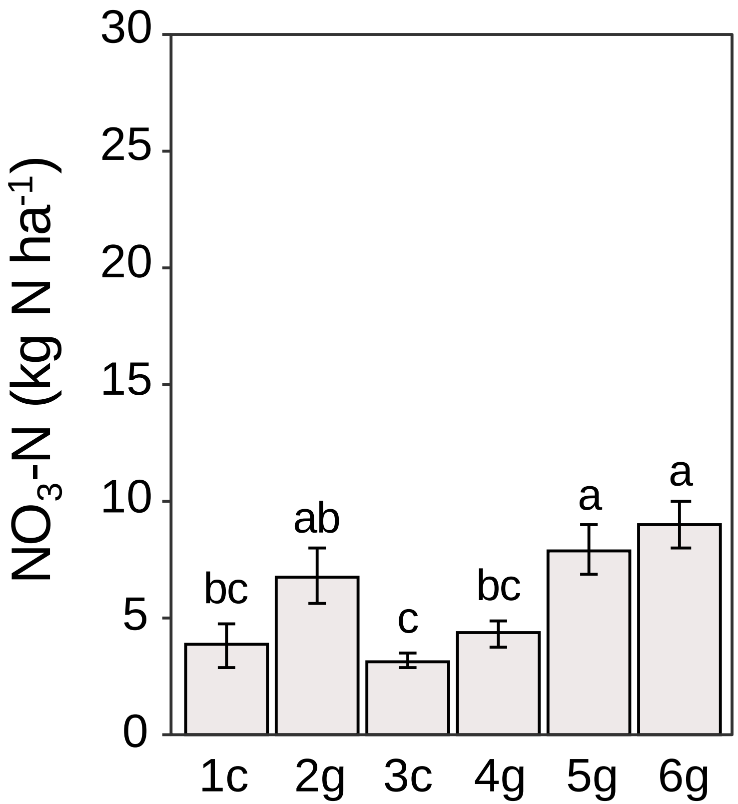
**Nitrate leaching to the groundwater was determined by sampling soil water with ceramic suction cups continuously during the winters 2016/17 to 2018/19. and analyzing it for $NO_3$-N-concentrations.**
**The volume of drainage water was calculated by a general climatic water balance model.**

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

## Over winter nitrate N leaching losses (kg N $ha^{-1}$) to the groundwater across differently managed grasslands and leys at Lindhof

(average over 3 leaching periods 2016/17 to 2018/19)

Different lower-case letters indicate significant differences at $P<0.05$




**Legend:**

1c: Permanent grassland
4 x cut for silage

2g: Permanent grassland
8 x grazed + 1 x cut for silage

3c: Grass clover, 1st production year,
4 x cut for silage

4g: Grass clover, year of establishment
after cereal harvest, 2 x grazed

5g: Grass clover, 1st production year,
9 x grazed + 1 x cut for silage

6g: Grass clover, 2nd production year,
8 x grazed + 2 x cut for silage

# Materials and Methods

Christian-Albrechts-Universität zu Kiel

**The <u>Product Carbon Footprint (PCF) for milk production</u> 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$^{-1}$**

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**Tab 4: 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 = Energy Corrected Milk. FA= Forage area on farm)**

| Parameter<br><br>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)

## Conclusion

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.

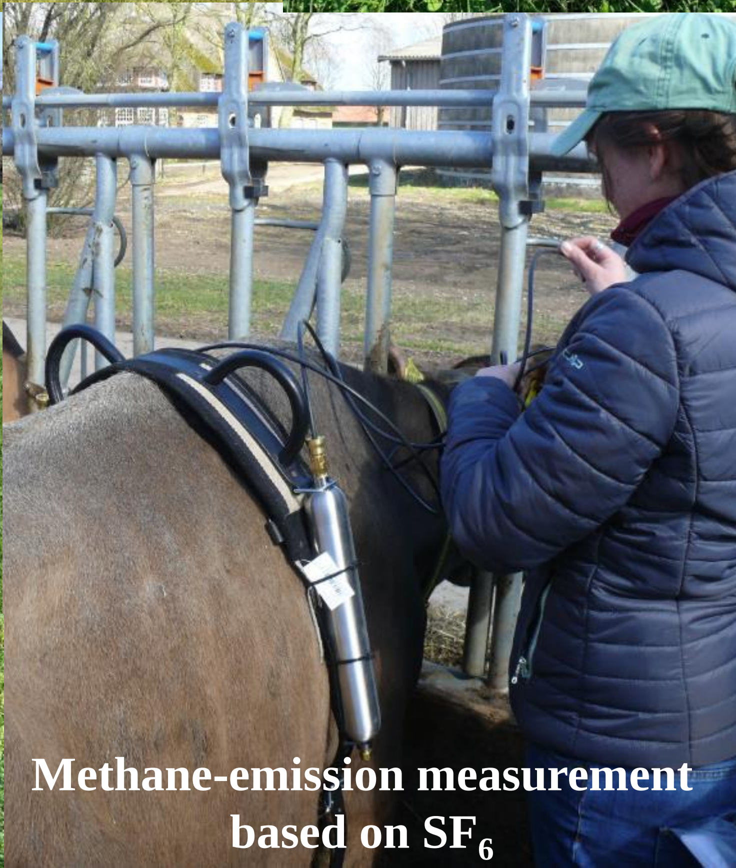
The findings underline the strength of ruminant-based crop-livestock systems as a tool towards ecological intensification under the temperate conditions of Northern Germany.

Further research projects regarding economic assessments, effects on faunistic biodiversity and GHG are ongoing or already published.

# More results next time

$CO_2$ and methane fluxes based on eddy covariance

Measurement of $N_2O$ emissions



Methane-emission measurement based on $SF_6$

# Recent publications:

Loza, C., Davis, H., Malisch, C., Taube, F., Loges, R., Magistrali, A., Butler, G., 2023. **Milk Fatty Acids: The Impact of Grazing Diverse Pasture and the Potential to Predict Rumen-Derived Methane**. Agriculture 13, 181. https://doi.org/10.3390/agriculture13010181

Beye H, Taube F, Lange K, Hasler M, Kluß C, Loges R, Diekötter T 2022. **Species-Enriched Grass-Clover Mixtures Can Promote Bumblebee Abundance** Compared with Intensively Managed Conventional Pastures. Agronomy, 12

Lorenz H, Reinsch T, Hess S, Taube F 2019. **Is low-input dairy farming more climate friendly? A meta-analysis of the carbon footprints of different production systems.** Journal of Cleaner Production 211, 161–170.

Nielsen KM 2021. **Lindhof laver mælk med lavt klimaaftryk**. Økologisk Landsforening (pdf, www)

Smit HPJ, Reinsch T, Kluß C, Loges R, Taube F 2021. **Very Low Nitrogen Leaching in Grazed Ley-Arable-Systems in Northwest Europe**. Agronomy. 11, 2155. https://doi.org/10.3390/agronomy11112155

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. 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.

Nyameasem JK, Malisch CS, Loges R, Taube F, Kluß C, Vogeler I, Reinsch T, 2021. **Nitrous Oxide Emission from Grazing Is Low across a Gradient of Plant Functional Diversity and Soil Conditions**. Atmosphere 12, 223. https://doi.org/10.3390/atmos12020223

Loges, R., Mues, S., Kluß, C., Malisch, C., Loza, C., Poyda, A., Reinsch, T., Taube, F., 2020b. **Dairy cows back to arable regions? Grazing leys for eco-efficient milk production systems**. Grassland Science in Europe 25, 400. (PDF)

Lorenz H, Reinsch T, Kluß C, Taube F, Loges R 2020. **Does the Admixture of Forage Herbs Affect the Yield Performance, Yield Stability and Forage Quality of a Grass Clover Ley?** Sustainability 12, 5842https://doi.org/10.3390/su12145842

Loges, R., Loza, C., Voss, P., Kluß, C., Malisch, C., Taube, F., 2020a. **The potential of multispecies swards for eco-efficient dairy production in Northern Germany.** Grassland Science in Europe 25, 312. (PDF)

Reinsch T, Malisch C, Loges R, Taube F 2020**. Nitrous oxide emissions from grass–clover swards as influenced by sward age and biological nitrogen fixation**. Grass Forage Sci gfs.12496. https://doi.org/10/gg668n

Loges R, Bunne I, Reinsch T, Malisch CS, Kluß C, Herrmann A, Taube F. 2018. **Forage production in rotational systems generates similar yields compared to maize monocultures but improves soil carbon stocks.** European Journal of Agronomy 97, 11-19 10.1016/j.eja.2018.04.010

# Thank you for listening

# Thank you for listening

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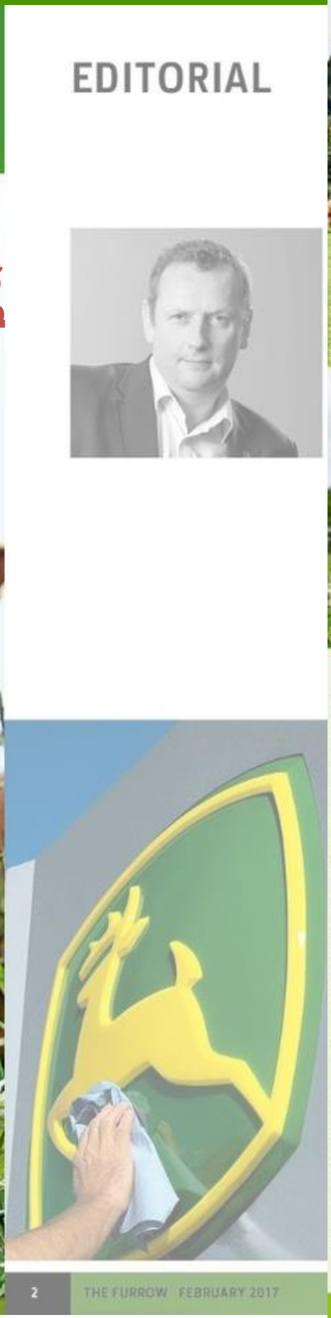




**top:** At the University of Kiel's trial farm, "Lindhof", researchers study the economic and ecological benefit of grazing systems. **left:** A testing installation for climate gas emissions on a trial field at "Lindhof".

**In Germany, turning cows out to pasture has become quite unusual – only 42% of cows have access to grassland. However, in 2014, 51.5% of consumers said they** wanted milk from grazed cows, and some supermarkets are now paying the equivalent of a 0.4p/litre premium for it.

The University of Kiel has been carrying out research on organic farming since 1994, and its findings are just as relevant to conventional producers. It has found that grassland farming lowers milk production costs, improves biodiversity and lowers dairy farms' $CO_2$ footprints.

The team is currently developing a pasture management system for differing landscape types, which will culminate in a Smart Grazing app. Due to be released in 2018, the app will forecast a farm's daily grass growth rates, based on data including weather, region, fertiliser and soil. The aim is to provide farmers with a decision-making tool: When to turn out, reseed, and cut silage, for example.

Lindhof – one of the university's research farms – is studying the economic and ecological benefits of grassland farming. It has found the best forage mix is high quality grass; to provide energy, with clover supplying the protein.

"In the past, farmers used to let the grass grow as high as their boots, but now we only let it grow to about 10cm," says scientific manager Ralf Loges. At this height, the cows can pluck up young grass with a single bite, reducing wastage and improving rumen efficiencies. Research has shown that purchased concentrates with an energy content of 10MJ cost around 41p, with maize silage of the same quality costing 22p. "With pasture feeding, the price can be significantly below 18p."

The project is already producing a lot of food for thought. "The abandonment of quotas and the drop in milk price have caused people to rethink things," Ralf explains. "We see this in the increasing number of visitors we have, especially conventional farmers." ■