Lowering the carbon footprint of pasture-based dairy production

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The carbon footprint of pasture-based milk production: Can white clover make a difference?

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ABSTRACT

Carbon footprint (CF) calculated by life cycle assessment (LCA) was used to compare greenhouse gas emissions from pasture-based milk production relying mainly on (1) fertilizer N (FN), or (2) white clover (WC). Data were sourced from studies conducted at Solohead Research Farm in Ireland between 2001 and 2006. Ten FN pastures stocked between 2.0 and 2.5 livestock units (LU)/ha with fertilizer N input between 180 and 353 kg/ha were compared with 6 WC pastures stocked between 1.75 and 2.2 LU/ha with fertilizer N input between 80 and 99 kg/ha. The WC-based system had 11 to 23% lower CF compared with FN (average CF was 0.86 to 0.87 and 0.97 to 1.13 kg of CO_2-eq/kg of energy-corrected milk, respectively, 91% economic allocation). Emissions of both N_2O and CO_2 were lower in WC, whereas emissions of CH_4 (per kg of energy-corrected milk) were similar in both systems. Ratio sensitivity analysis indicated that the difference was not caused by error due to modeling assumptions. Replacing fertilizer N by biological nitrogen fixation could lower the CF of pasture-based milk production.
Key words: carbon footprint, life cycle assessment, white clover, milk production

INTRODUCTION

Because of projected population growth and demand for dairy products (Steinfeld et al., 2006), urgent action is needed to achieve a sustainable balance between profitability and the environmental impact of dairy production. The global dairy sector was estimated to

of the output of Irish agricultural commodities (Anonymous, 2011), GHG emissions from milk are important to policy makers. Tools are needed to assist with strategic policy development to enable the dairy sector to thrive while minimizing GHG emissions.

Life cycle assessment (**LCA**; ISO, 2006) has been developed to assess the environmental impact through the life cycle of products, from the "cradle" (production of raw materials such as iron ore) to the "grave" (the waste management of products after consumption). When applied to agricultural products, attention is often focused on "cradle to farm gate" because the greatest impact is found in the production stage (Schau and Fet, 2007). Because of global concerns about GHG emissions from livestock production, the LCA interpretation of GHG emissions is performed more often than other impact categories (e.g., eutrophication) and is referred to as carbon footprint (**CF**; O'Brien et al., 2010; Rotz et al., 2010; Flysjö et al., 2011). The main GHG from agriculture are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). For pasture-based milk production, mineral fertilizer and recycled organic manures are the main N inputs to grassland and the main sources of N_2O emissions from farms. Typical management in grazing systems uses mineral fertilizer N (**FN**) as the predominant source of N for grassland (referred to as hereafter as FN management) in addition to manure.

In temperate pastures, biological N fixation (**BNF**) from forage legumes can also be a significant source of N (10 to 300 kg of N/ha per year; Ledgard et al., 2009). Because of increasing fertilizer prices and stringent regulation of N use on farms (European Council,

Published in 2012

16% reduction in carbon footprint of milk

RSF-07-516: 'Quantification of the potential of white clover to lower GHG emissions from Irish grassland-based dairy production

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NDP
National Development Plan 2007 - 2013

Department of Agriculture, Fisheries and Food
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SSTI
Strategy for Science, Technology and Innovation

Grass and Forage Science
The Journal of the British Grassland Society | The Official Journal of the European Grassland Federation

An economic comparison of systems of dairy production based on N-fertilized grass and grass-white clover grassland in a moist maritime environment

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Published in 2012

No difference in profitability

Abstract

This study compared the profitabilities of systems of dairy production based on N-fertilized grass (FN) and grass-white clover (WC) grassland and assessed sensitivity to changing fertilizer N and milk prices. Data were sourced from three system-scale studies conducted in Ireland between 2001 and 2009. Ten FN stocked between 2·0 and 2·5 livestock units (LU) ha^{-1} with fertilizer N input between 173 and 353 kg ha^{-1} were compared with eight WC stocked between 1·75 and 2·2 LU ha^{-1} with fertilizer N input between 79 and 105 kg ha^{-1}. Sensitivity was confined to nine combinations of high, intermediate and low fertilizer N and milk prices. Stocking density, milk and total sales from WC were approximately 0·90 of FN. In scenarios with high fertilizer N price combined with intermediate or low milk prices, WC was more ($P < 0·05$) profitable than FN. Based on milk and fertilizer N prices at the time, FN was clearly more profitable than WC

Introduction

In the 10 years since 2000, the cost of fertilizer N in Ireland has been increasing at an annual rate of around 9% (Figure 1a) owing to growing demand worldwide and rising manufacturing costs (Prince *et al.*, 2009). In contrast, the milk price in Ireland, though variable, has been relatively static (Figure 1b). Hence, there has been a strong increase in the cost of fertilizer N relative to the farm-gate price for milk (Figure 1c). This is negatively impacting on profitability of pasture-based systems of dairy production, which are highly reliant on inputs of fertilizer N. At the same time, in the European Union and in other parts of the world, there has been increasing regulatory pressure to lower the losses of N to water and to the atmosphere: for example, various national regulations stemming from the Nitrates Directive, Water Framework Directive and the National Emission Ceilings Directive (European Council, 1991;

Negligible nitrous oxide emissions associated with biological N fixation

OPEN ACCESS Freely available online
PLoS one

Measured and Simulated Nitrous Oxide Emissions from Ryegrass- and Ryegrass/White Clover-Based Grasslands in a Moist Temperate Climate

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Abstract

There is uncertainty about the potential reduction of soil nitrous oxide (N_2O) emission when fertilizer nitrogen (FN) is partially or completely replaced by biological N fixation (BNF) in temperate grassland. The objectives of this study were to 1) investigate the changes in N_2O emissions when BNF is used to replace FN in permanent grassland, and 2) evaluate the applicability of the process-based model DNDC to simulate N_2O emissions from Irish grasslands. Three grazing treatments were: (i) ryegrass (*Lolium perenne*) grasslands receiving 226 kg FN ha^{-1} yr^{-1} (GG+FN), (ii) ryegrass/white clover (*Trifolium repens*) grasslands receiving 58 kg FN ha^{-1} yr^{-1} (GWC+FN) applied in spring, and (iii) ryegrass/white clover grasslands receiving no FN (GWC-FN). Two background treatments, un-grazed swards with ryegrass only (G–B) or ryegrass/white clover (WC–B), did not receive slurry or FN and the herbage was harvested by mowing. There was no significant difference in annual N_2O emissions between G–B (2.38±0.12 kg N ha^{-1} yr^{-1} (mean±SE)) and WC-B (2.45±0.85 kg N ha^{-1} yr^{-1}), indicating that N_2O emission due to BNF itself and clover residual decomposition from permanent ryegrass/clover grassland was negligible. N_2O emissions were 7.82±1.67, 6.35±1.14 and 6.54±1.70 kg N ha^{-1} yr^{-1}, respectively, from GG+FN, GWC+FN and GWC-FN. N_2O fluxes simulated by DNDC agreed well with the measured values with significant correlation between simulated and measured daily fluxes for the three grazing treatments, but the simulation did not agree very well for the background treatments. DNDC overestimated annual emission by 61% for GG+FN, and underestimated by 45% for GWC-FN, but simulated very well for GWC+FN. Both the measured and simulated results supported that there was a clear reduction of N_2O emissions when FN was replaced by BNF.

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Introduction

Nitrous oxide (N_2O) is a potent greenhouse gas (GHG) with a global warming potential 298 times higher than carbon dioxide

[6], and is often enhanced where available N exceeds plant requirements, especially under wet conditions [7]. Agricultural activities have significantly enhanced N_2O emissions by increasing available N in soils through application of fertilizer N (FN) and

Global Change Biology celebrating 20 years

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Interannual variation in nitrous oxide emissions from perennial ryegrass/white clover grassland used for dairy production

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Abstract

Nitrous oxide (N_2O) emissions are subject to intra- and interannual variation due to changes in weather and management. This creates significant uncertainties when quantifying estimates of annual N_2O emissions from grazed grasslands. Despite these uncertainties, the majority of studies are short-term in nature (<1 year) and as a consequence, there is a lack of data on interannual variation in N_2O emissions. The objectives of this study were to (i) quantify annual N_2O emissions and (ii) assess the causes of interannual variation in emissions from grazed perennial ryegrass/white clover grassland. Nitrous oxide emissions were measured from fertilized and grazed perennial ryegrass/white clover grassland (WC) and from perennial ryegrass plots that were not grazed and did not receive N

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Legume Futures

SEVENTH FRAMEWORK PROGRAMME

Negligible nitrous oxide emissions associated with biological N fixation

Pulse of Nitrous oxide released after each application of fertilizer N

Direct N_2O emission from BNF *per se* is negligible (Rochette and Janzen, 2005; Carter and Ambus, 2006; Li et al., 2011; Jensen et al., 2012)

2019R521: Lowering the carbon and ammonia footprints of pasture-based dairy production

Target: 50% reduction in the Carbon footprint of milk

i.e. 0.6 kg CO_2eq. per litre of milk

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Greenhouse gasses: Methane, nitrous oxide and carbon dioxide

Ammonia: trans-boundary gas

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Methane (50%)

Methane (50%)

Replacement Rate

Nitrous oxide (20%)

Methane (50%)

Replacement Rate

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Nitrous oxide (20%)

Methane (50%)

Replacement Rate

Low emissions slurry spreading & grazing season length

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Nitrous oxide (20%)

Methane (50%)

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Replacement Rate

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Replacement Rate

Protected urea
White and Red Clover

Nitrous oxide (20%)

Methane (50%)

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Replacement Rate

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Numbers

Nitrous oxide

(20%)

Methane (50%)

Low emissions slurry spreading
& grazing season length

Replacement
Rate

Nitrogen

Nitrous oxide

(20%)

Protected urea
White and Red Clover

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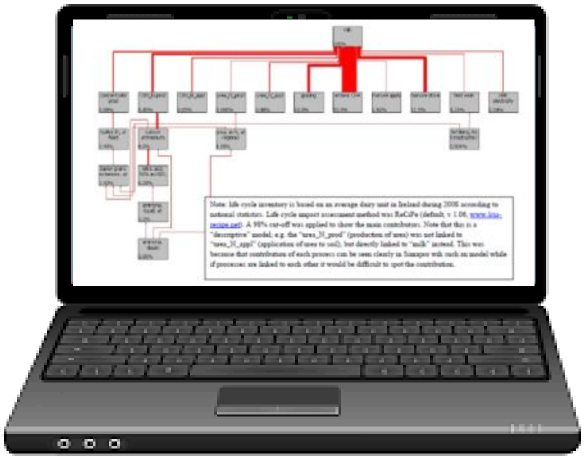
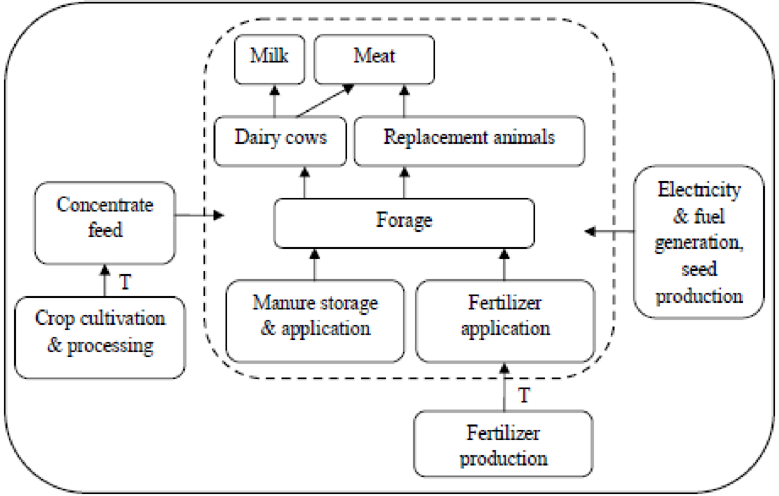
Systems Analysis





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1. Standard system: 2.5 LU/ha, 280 kg/ha fertilizer N (Urea and CAN) & splash plate slurry application

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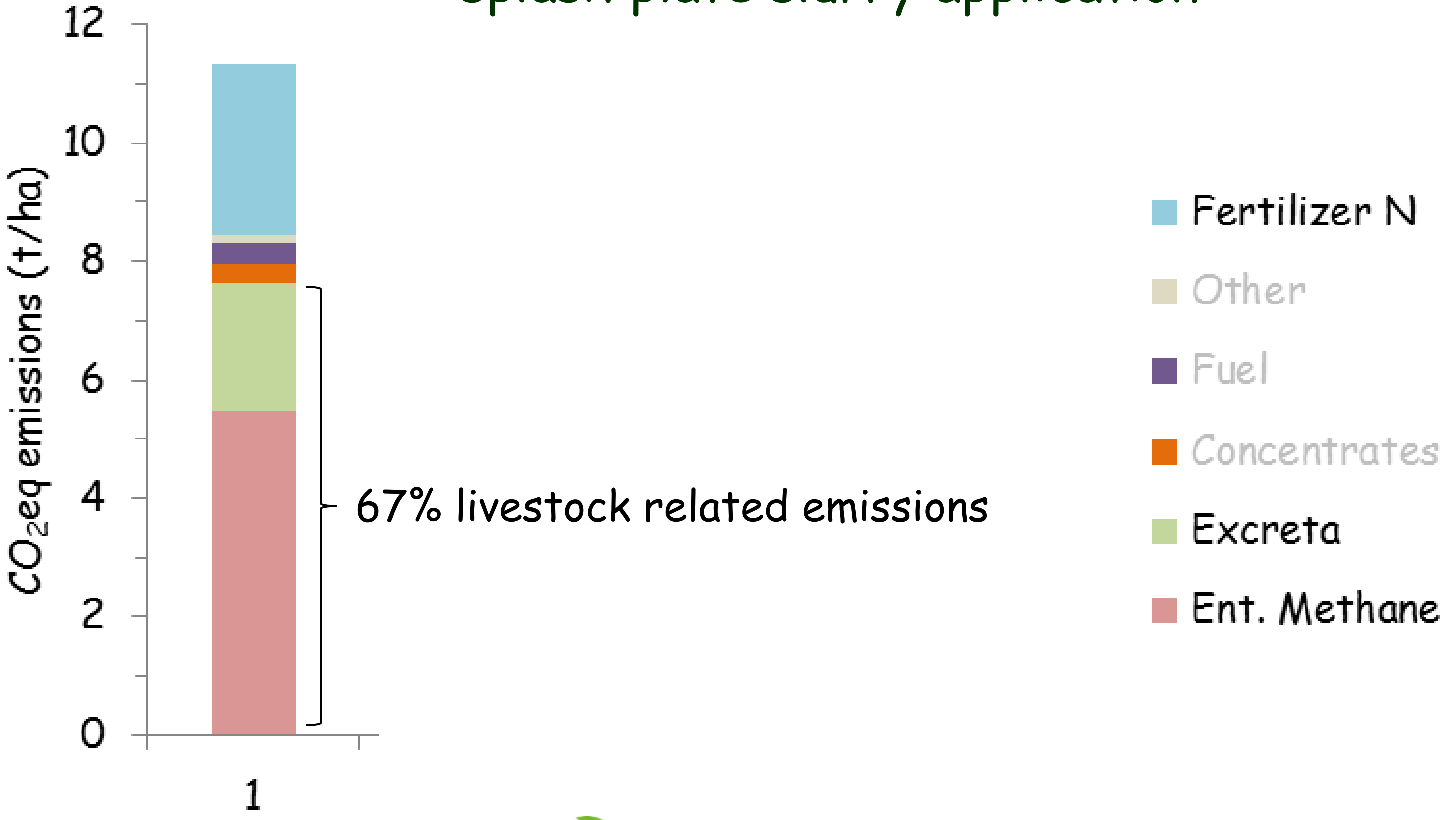

MB

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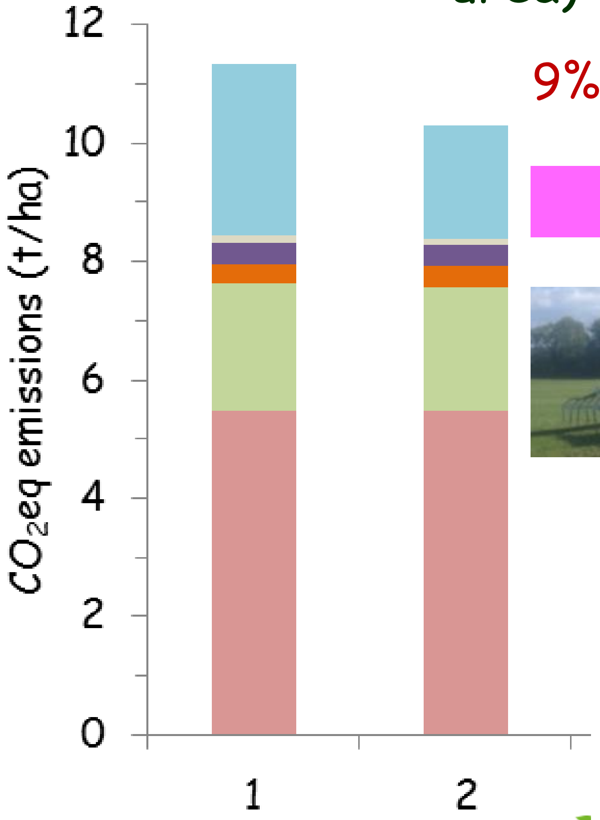
TRansition paths to sUstainable legume-based systems in Europe

https://www.true-project.eu/

2. Protected urea & LESS: 2.5 LU/ha, 250 kg/ha fertilizer N (Protected urea) & band slurry application

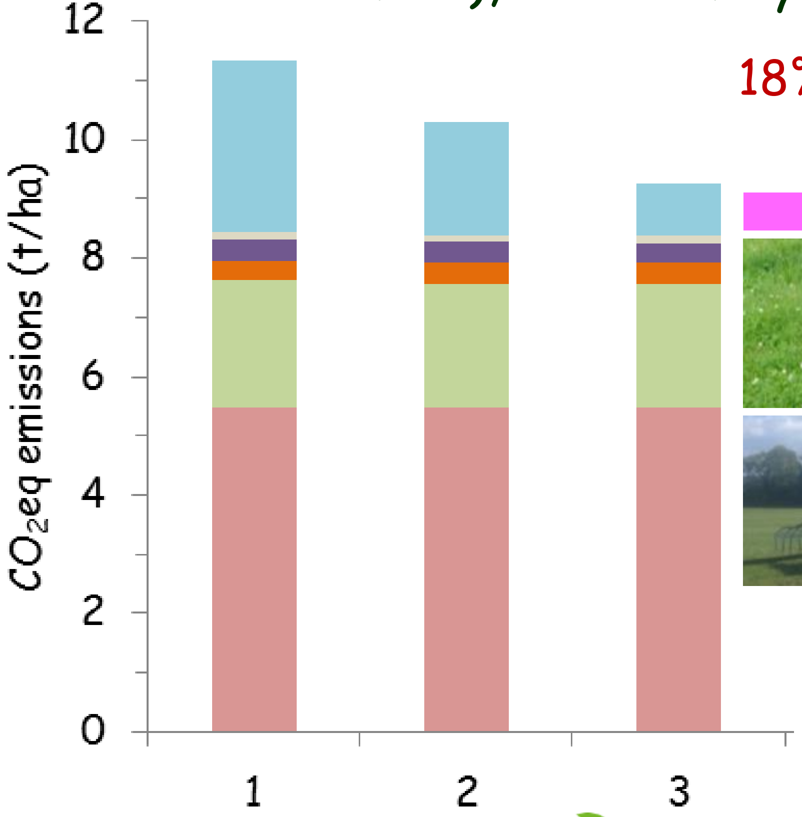


9% lower emissions

NBPT urea

3. Pro-Urea, LESS & Clover: 2.5 LU/ha, 125 kg/ha fertilizer N (Protected urea), band slurry application & Clover

18% lower emissions

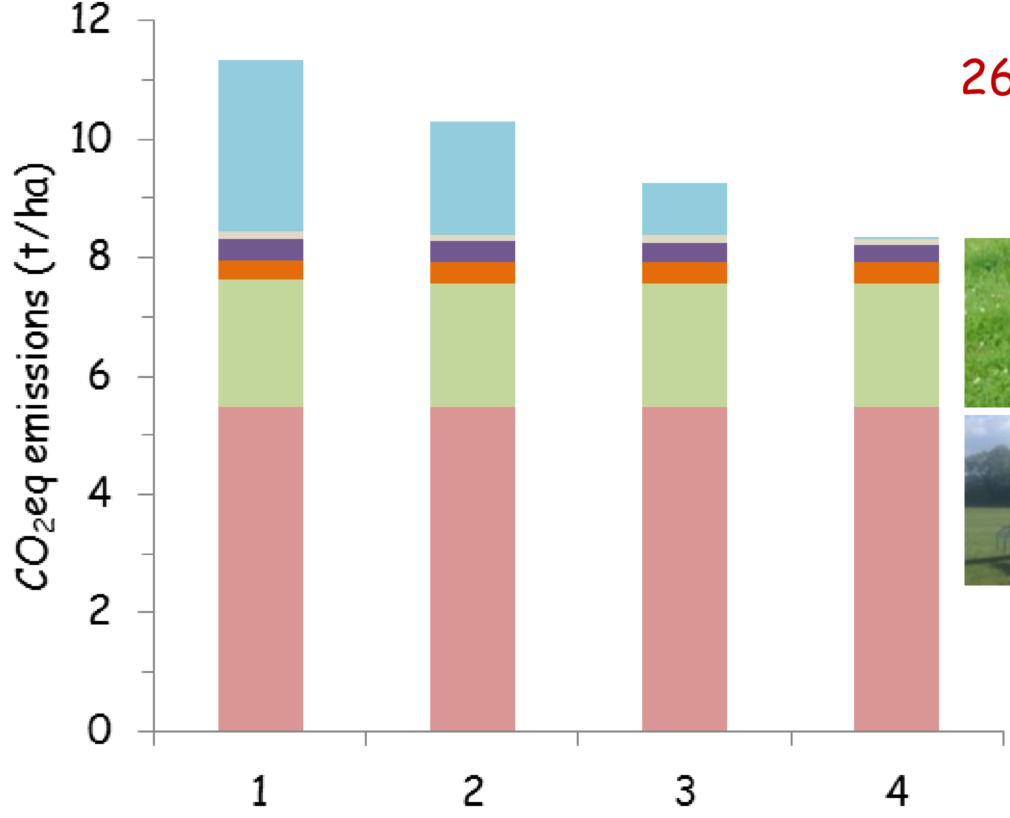


NBPT urea

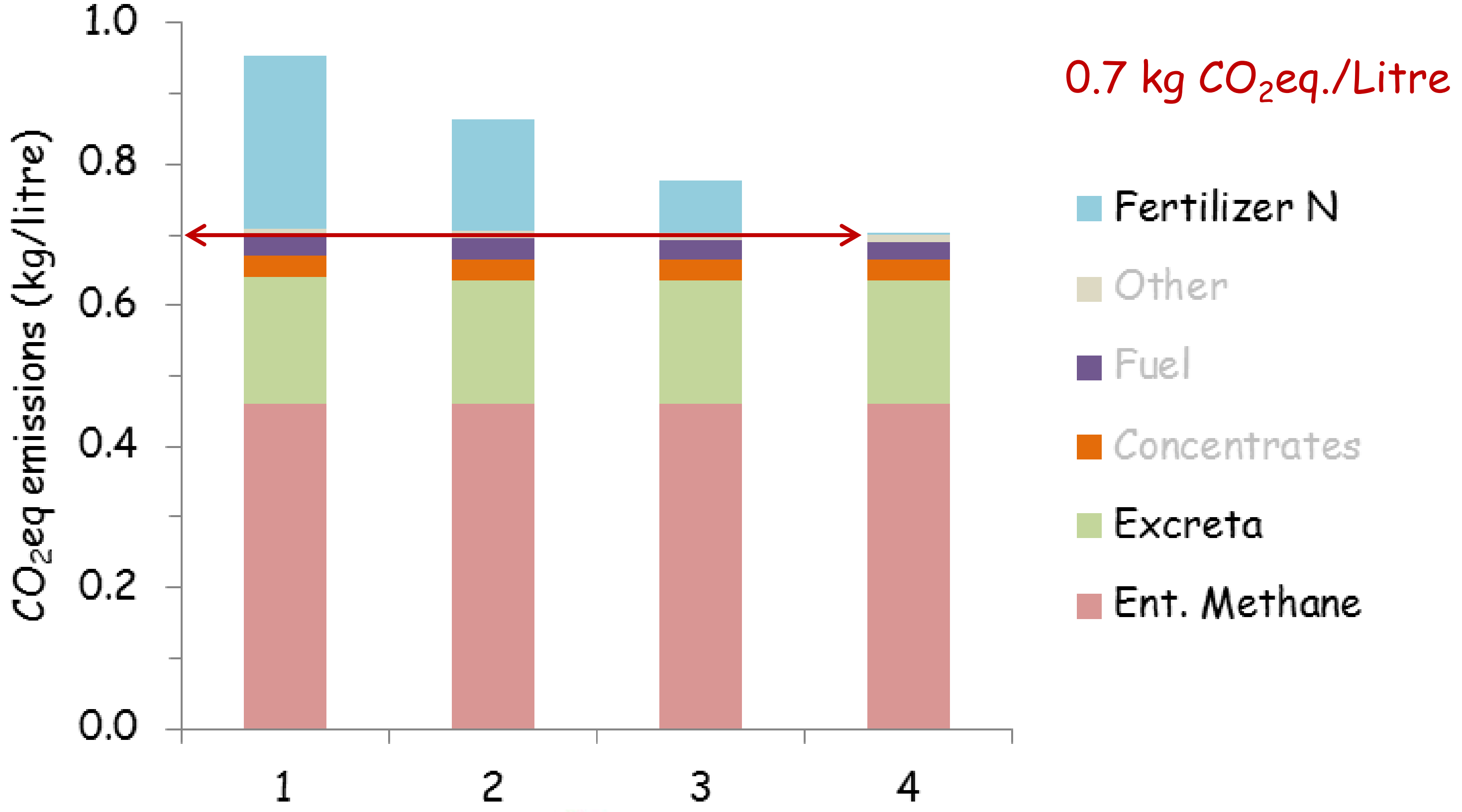
DEH

4. Clover & LESS: 2.5 LU/ha, 0 kg/ha fertilizer N, band slurry application & Clover based swards

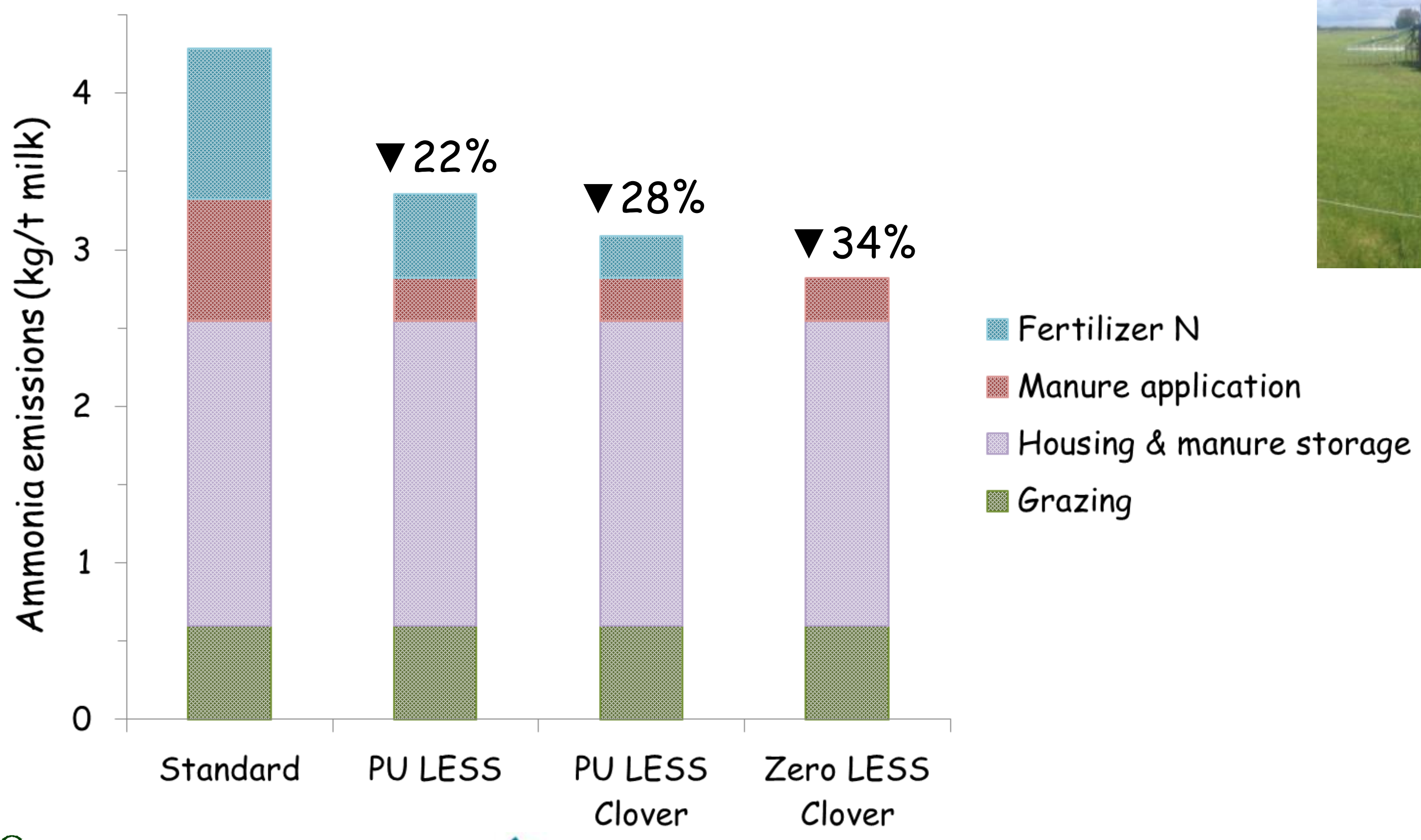
26% lower emissions



4. Clover & LESS: 2.5 LU/ha, 0 kg/ha fertilizer N, band slurry application & Clover based swards

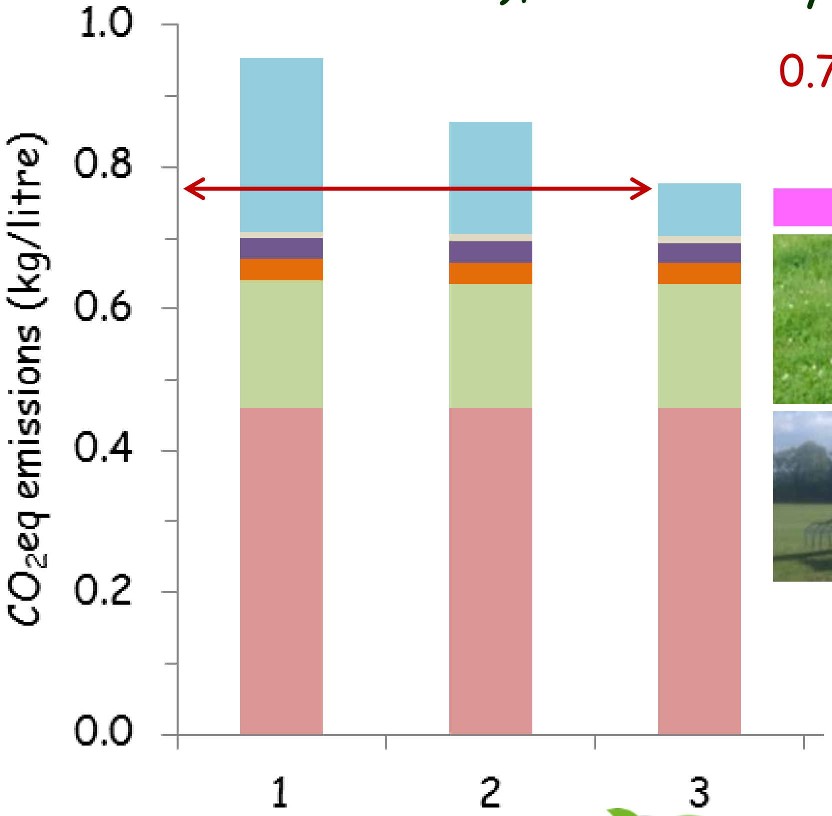


Ammonia Emissions



3. Pro-Urea, LESS & Clover: 2.5 LU/ha, 125 kg/ha fertilizer N (Protected urea), band slurry application & Clover

0.78 kg CO2eq.: 35% lower than national average



NBPT urea

- Fertilizer N
- Other
- Fuel
- Concentrates
- Excreta
- Ent. Methane

TRansition paths to sUstainable legume-based systems in Europe

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Technical and economic performance

Performance of clover-based system at Solohead: soil lime status, P & K, EBI

17,500 L/ha or 1400 kg MS/ha off the milking platform

Emissions per Litre milk = 0.78 kg CO_2eq. 35% lower than the national average.

Economics

No difference in profitability (Humphreys et al., 2012)

Clover-based system is more profitable (McClearn et al., 2020)

Grass-clover system with 100 to 150 kg/ha protected urea can be at least as profitable as a high fertilizer N input grass-only system

Other Aspects

Stocking rate: Carbon footprint per € rather than per ha or per litre

EBI: Small incremental improvements at Solohead; big impact nationally

Soil sequestration: Carbon-neutral reseeding in a 10 year time-frame

Land drainage: Lower N_2O emissions and higher clover productivity

Sexed semen: improvement in quality of calf-to-beef

Hedgerows

Implications

Four years to convert to a clover-based system

Change sward species composition – change grassland management

Solohead: High stocked system with low environmental footprints

Paris Agreement: Sustainable intensification of food production

Derogation?

Marketing opportunities for low CF milk (0.78 kg CO_2eq./L)

Organic dairy production – opportunity?

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Conclusions

NBPT urea & LESS could be adopted today – 9% reduction in emissions

Larger obstacles to adopting clover-based systems

Clover-based systems are economically competitive

Growing global demand for food & Sustainable intensification

Marketing opportunities for food with low environmental footprints

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