Lowering the carbon footprint of pasture-based dairy production

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Teagasc, Livestock Systems
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 Soloshead 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 90 kg/ha. The WC-based system had 11 to 23% lower CF compared with FN (average CF = 0.66 to 0.87 and 0.97 to 1.13 kg of CO2eq/kg of energy-corrected milk, respectively, 91% economic allocation). Emissions of both N2O and CO2 were lower in WC, whereas emissions of CH4 (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 (Solfeldt 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 emit 20% of global carbon emissions (GHG) 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 Jet, 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; Fross et al., 2011). The main GHG from agriculture are carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Pasture-based milk production, mineral fertilizer and recycled organic manures are the main N inputs to grassland and the main sources of N2O emissions from forms. Typical management in grazing systems uses mineral fertilizer N (FN) as the predominant source of N for grassland (referred to hereafter as FN management) in addition to manure. In temperate pastures, biological N fixation (BNF) from legumes can also be a significant source of N (10 to 300 kg of N/ha per year; Ledgard et al., 2000). Because of increasing fertilizer prices and stringent regulation of N use on farms (European Council,
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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Abstract
This study compared the profitability 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 3.5 livestock units (LU) ha⁻¹ with fertilizer N input between 175 and 355 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 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
Negligible nitrous oxide emissions associated with biological N fixation

Pulse of Nitrous oxide released after each application of fertilizer N

Direct N₂O 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$_2$eq. per litre of milk

Greenhouse gases: Methane, nitrous oxide and carbon dioxide

Ammonia: trans-boundary gas
Methane (50%)
Methane (50%)

More lifetime milk per cow

Replacement Rate
Nitrous oxide (20%)

Methane (50%)

More lifetime milk per cow

Replacement Rate
Nitrous oxide (20%)

Methane (50%)

Low emissions slurry spreading & grazing season length

More lifetime milk per cow

Replacement Rate
Low emissions slurry spreading & grazing season length

Replacing rate

More lifetime milk per cow

Methane (50%)

Nitrous oxide (20%)

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Methane (50%)

Nitrous oxide (20%)

Low emissions slurry spreading & grazing season length

More lifetime milk per cow

Replacement Rate

Protected urea
White and Red Clover
Nitrous oxide (20%)

Methane (50%)

Nitrous oxide (20%)

More lifetime milk per cow

Replacement Rate

Low emissions slurry spreading & grazing season length

Protected urea
White and Red Clover

C sequestration

Protected urea
White and Red Clover
Nitrous oxide (20%) → Replacement Rate → More lifetime milk per cow → Protected urea
Nitrous oxide (20%) → Low emissions slurry spreading & grazing season length → White and Red Clover
Numbers

Nitrous oxide (20%)

Methane (50%)

More lifetime milk per cow

Low emissions slurry spreading & grazing season length

Nitrogen

Nitrous oxide (20%)

Replacement Rate

Protected urea
White and Red Clover

Numbers

Nitrous oxide (20%)

Methane (50%)

More lifetime milk per cow

Low emissions slurry spreading & grazing season length

Nitrogen

Nitrous oxide (20%)

Replacement Rate

Protected urea
White and Red Clover
Systems Analysis
1. Standard system: 2.5 LU/ha, 280 kg/ha fertilizer N (Urea and CAN) & splash plate slurry application

https://www.true-project.eu/
1. **Standard system**: 2.5 LU/ha, 280 kg/ha fertilizer N (Urea and CAN) & splash plate slurry application

67% livestock related emissions
2. Protected urea & LESS: 2.5 LU/ha, 250 kg/ha fertilizer N (Protected urea) & band slurry application

9% lower emissions

![Diagram showing CO₂eq emissions (t/ha) between two methods. Method 2 shows lower emissions.](https://www.true-project.eu/)
3. Pro-Urea, LESS & Clover: 2.5 LU/ha, 125 kg/ha fertilizer N (Protected urea), band slurry application & Clover

18% lower emissions

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

https://www.true-project.eu/
4. **Clover & LESS**: 2.5 LU/ha, 0 kg/ha fertilizer N, band slurry application & Clover based swards

![Graph showing CO₂eq emissions with categories: Fertilizer N, Other, Fuel, Concentrates, Excreta, Ent. Methane. The graph indicates 26% lower emissions.]
4. Clover & LESS: 2.5 LU/ha, 0 kg/ha fertilizer N, band slurry application & Clover based swards

0.7 kg CO$_2$eq./Litre

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

- **Standard**
- **PU LESS**
- **PU LESS Clover**
- **Zero LESS Clover**

- **Fertilizer N**
- **Manure application**
- **Housing & manure storage**
- **Grazing**

- **▼ 22%**
- **▼ 28%**
- **▼ 34%**

Ammonia emissions (kg/† milk)
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

https://www.true-project.eu/
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$_2$eq. 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$_2$O 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$_2$eq./L)

Organic dairy production - opportunity?
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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