AGRI-FOOD
& BIOSCIENCES
INSTITUTE

Leading | Protecting | Enhancing

Dairy Symposium 30.09.19

Improving carbon efficiency in dairy systems

Dr Debbie McConnell
Agriculture Branch

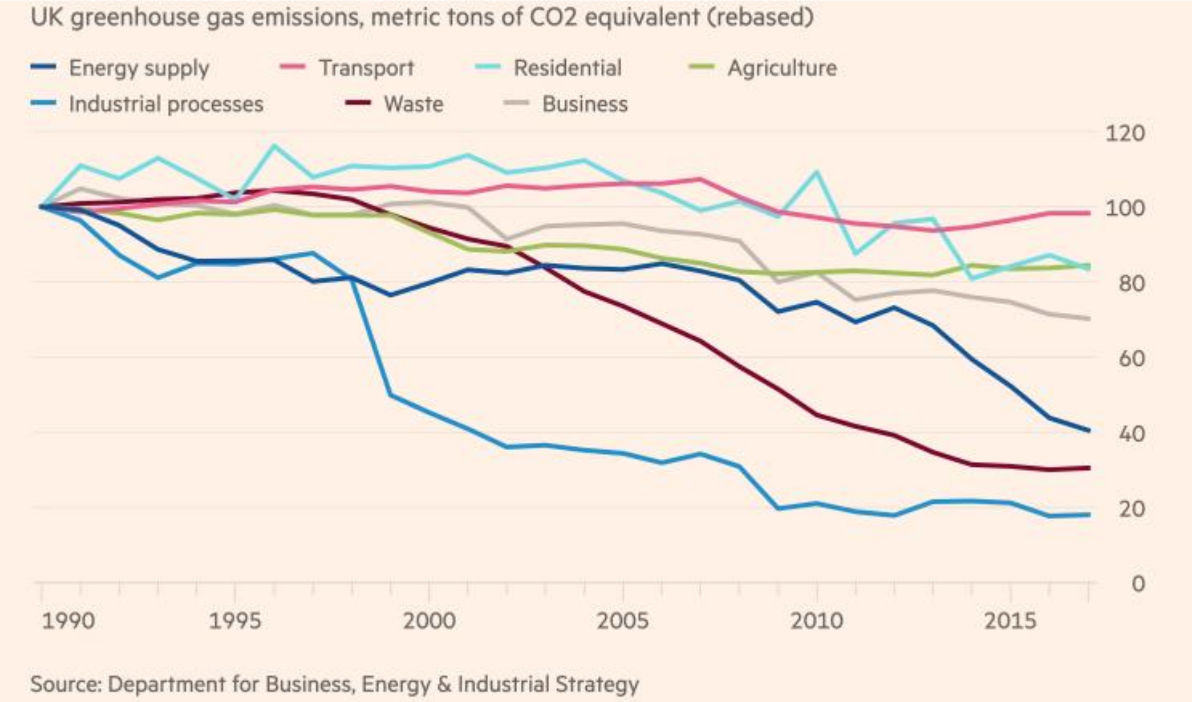
afbini.gov.uk

Improving carbon efficiency in dairy systems

- Agriculture currently accounts for 10 and 23% of UK and NI emissions, respectively

- Steady reductions since 1990 in emissions

- But… continued drive for sustainability in food production systems



GOV.UK

UK becomes first major economy to pass net zero emissions law

AFBI - Agriculture Branch

- **300 cow dairy herd**

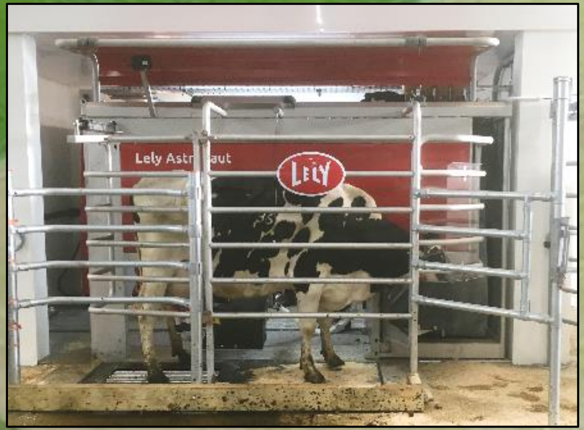
(predominantly Holstein; top 1% UK £PLI)

- **250 Youngstock**

- **Facilities:**
  - 50 point rotary parlour
  - 1 x robotic milking machine
  - Precision grassland platform

Research themes:

- Precision nutrition
- Reducing and replacing proteins
- Improving grass utilisation
- Environmental sustainability – GHG, P, Ammonia
- Farm systems modelling



Improving carbon efficiency in dairy systems

Grassland

C sequestration, N_2O emissions

Animal

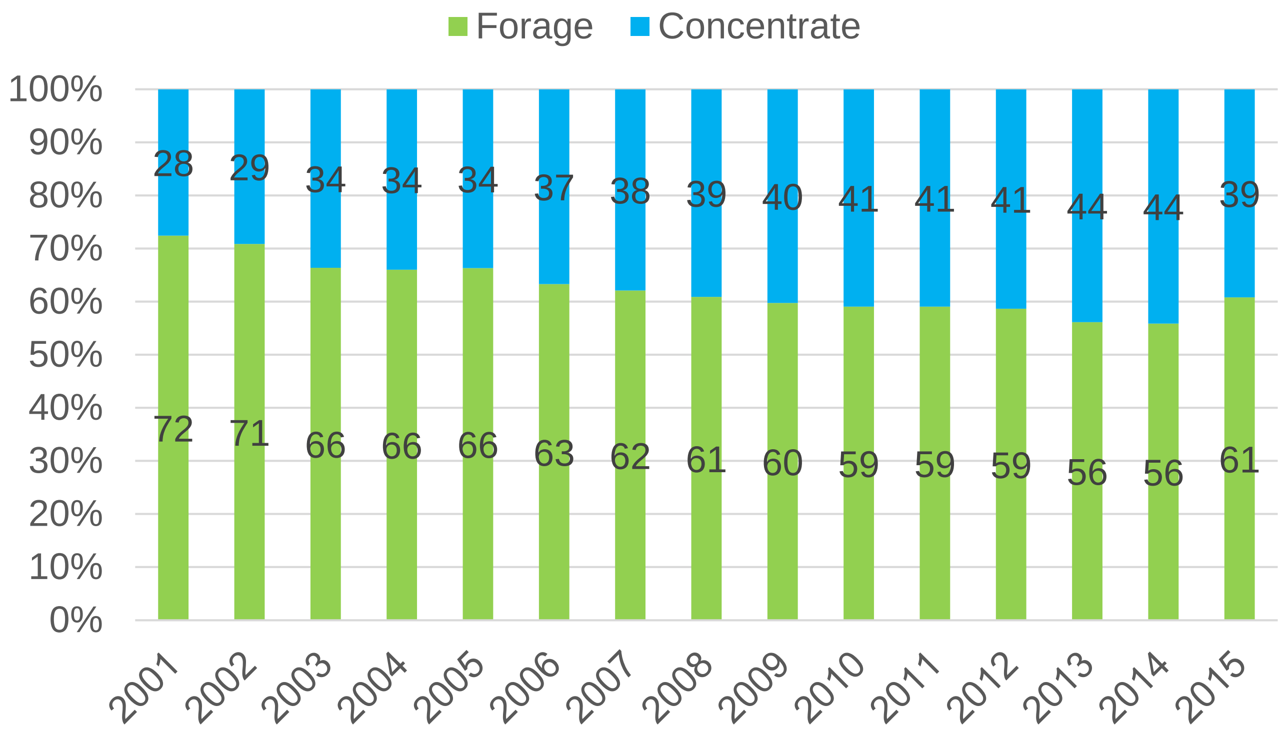
Enteric methane emissions

AGRI-FOOD
& BIOSCIENCES
INSTITUTE

N.I. Grassland

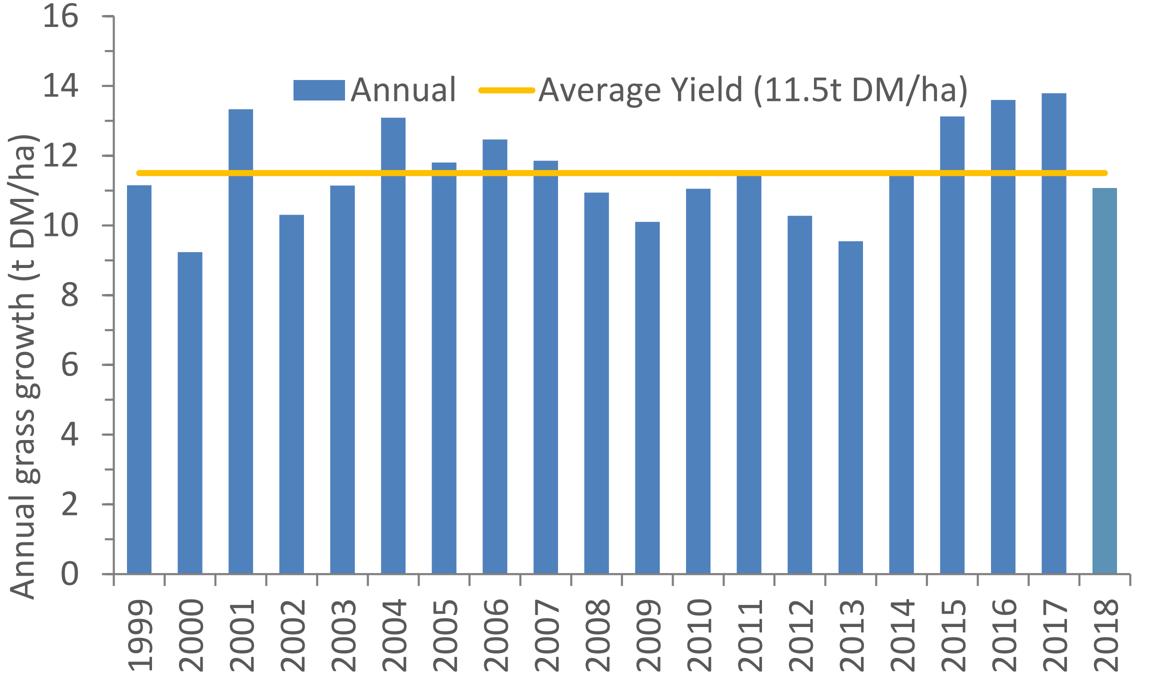
- Grassland occupies **91%** of the agricultural area of N.I. and contributes to **58%** of dairy cow diets

Proportion of dairy cow diets as forage or concentrate on N.I. dairy farms between 2001 and 2015. (Source: Cafre Benchmarking Data)



- Cool, humid climate suitable for high grass productivity:
  - 250 – 265d growing season
  - 1138mm annual rainfall

NI GrassCheck plot productivity 1999 - 2018



The role of grass – improving profitability

- Well-managed grazed grass remains the lowest cost feed stuff available
- Improving performance from forage associated with increased profit on dairy farms
- Increased use of home-grown feeds reduces exposure to input price volatility

Cow performance and net margin for bottom and top 25% of milk from forage farms 2000 – 2016 (CAFRE, 2017)

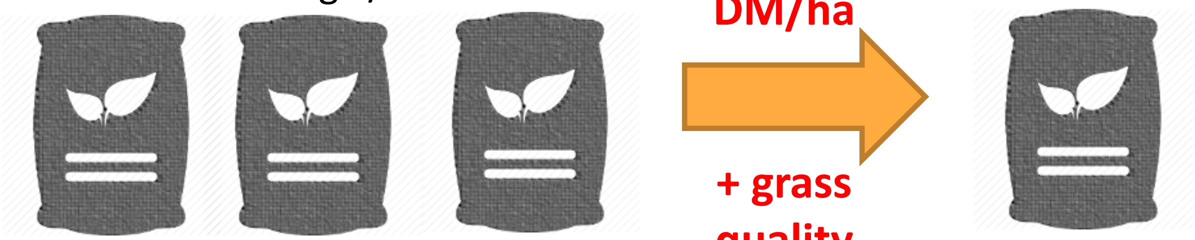
	Bottom 25%	Top 25%	Difference
Yield per cow (litres)	6893	6943	+ 50
Conc. feed rate (kg/litre)	0.39	0.23	- 0.16
Milk from forage (litres/cow)	949	3394	**+ 2445**
Net profit (£/cow)	**292**	**556**	**+ 264**

Every additional 1000 litres from forage = +£10 800 profit per 100 cows

AGRI-FOOD & BIOSCIENCES INSTITUTE

The role of grass – reducing environmental footprint

- Increasing use of home-grown forages, especially grass, provides opportunity to lower environmental footprint, including:
  - Reduced phosphorus balances



  - Lower water footprint:

    Forages: Grass = 690m3/t, Silage = 540m3/t

    Concentrate: Soya = 2640m3/t, Barley = 740m3/t, Rape meal = 730m3/t

  - Reduced ammonia emissions

System	kg NH_3 / cow / annum	Milk yield L / cow / annum	g NH_3 / L milk
Fully Confined	58.8	8500	6.9
Grazing / Housing	37.4	7220	5.2

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

The role of grass - Carbon sequestration

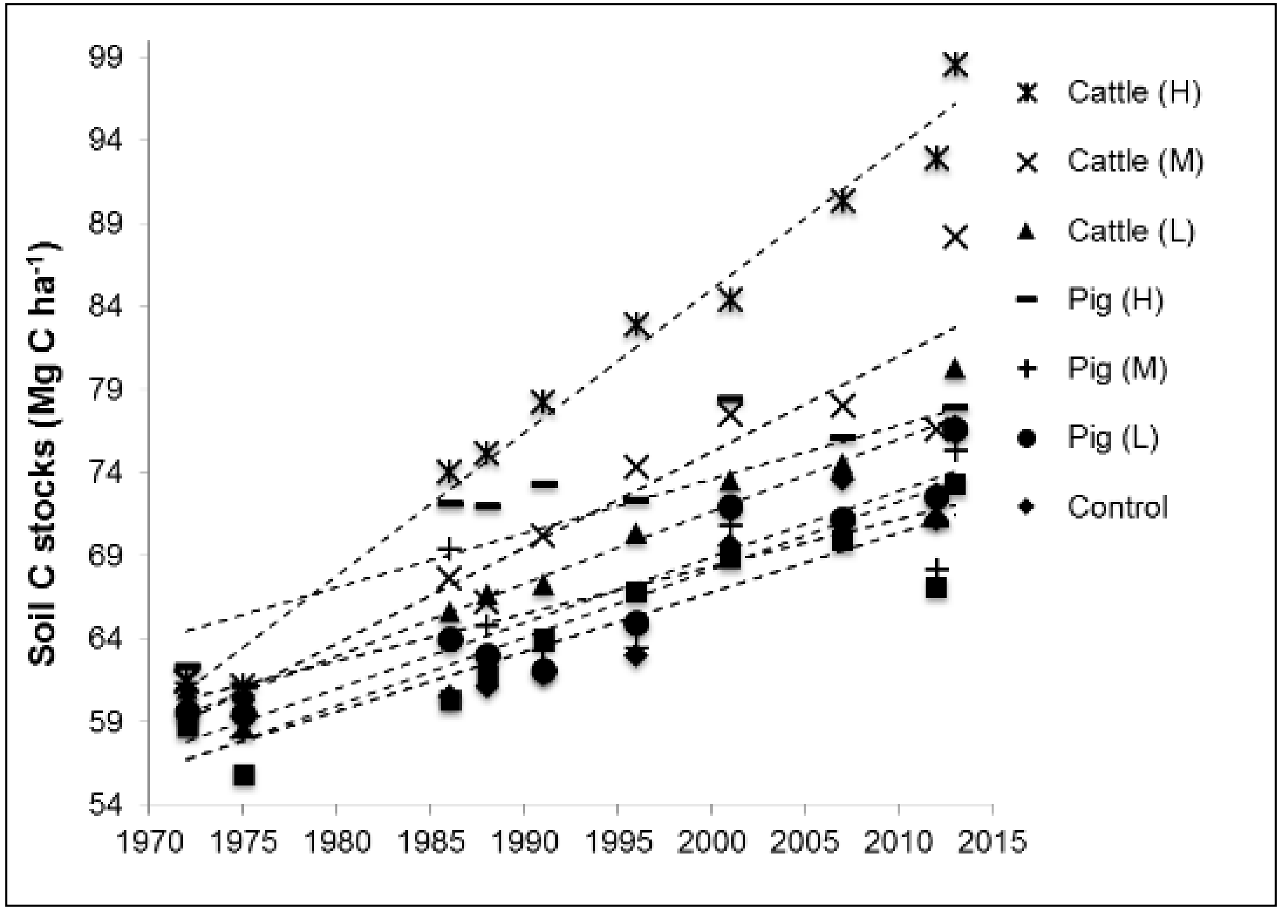
- IPCC estimates C sequestration potential can be reached after 20 years
- Long-term slurry trial established at AFBI – Hillsborough 1970
- Treatments:
  - Control (unfertilized)
  - NPK (200 kg N ha^{-1} yr^{-1})
  - Pig slurry at 50, 100, 200 m^3 ha^{-1} yr^{-1}
  - Cattle slurry at 50, 100, 200 m^3
- Measurements of grass offtake and soil organic stores over 50 year period

AGRI-FOOD & BIOSCIENCES INSTITUTE

Fornara *et al.* 2016, *Biogeosciences*

Long-term slurry trials – key observations

- All soils continuing to sequester C after 50 years
- Continued slurry amendments increased C sequestration rates:
  - Control (no slurry): 0.35t C/ha/yr
  - Cattle slurry (200m3/ha): 0.86t C/ha/yr
- No anticipated reduction in C sequestration rates



AGRI-FOOD & BIOSCIENCES INSTITUTE

Fornara *et al.* 2016, *Biogeosciences*

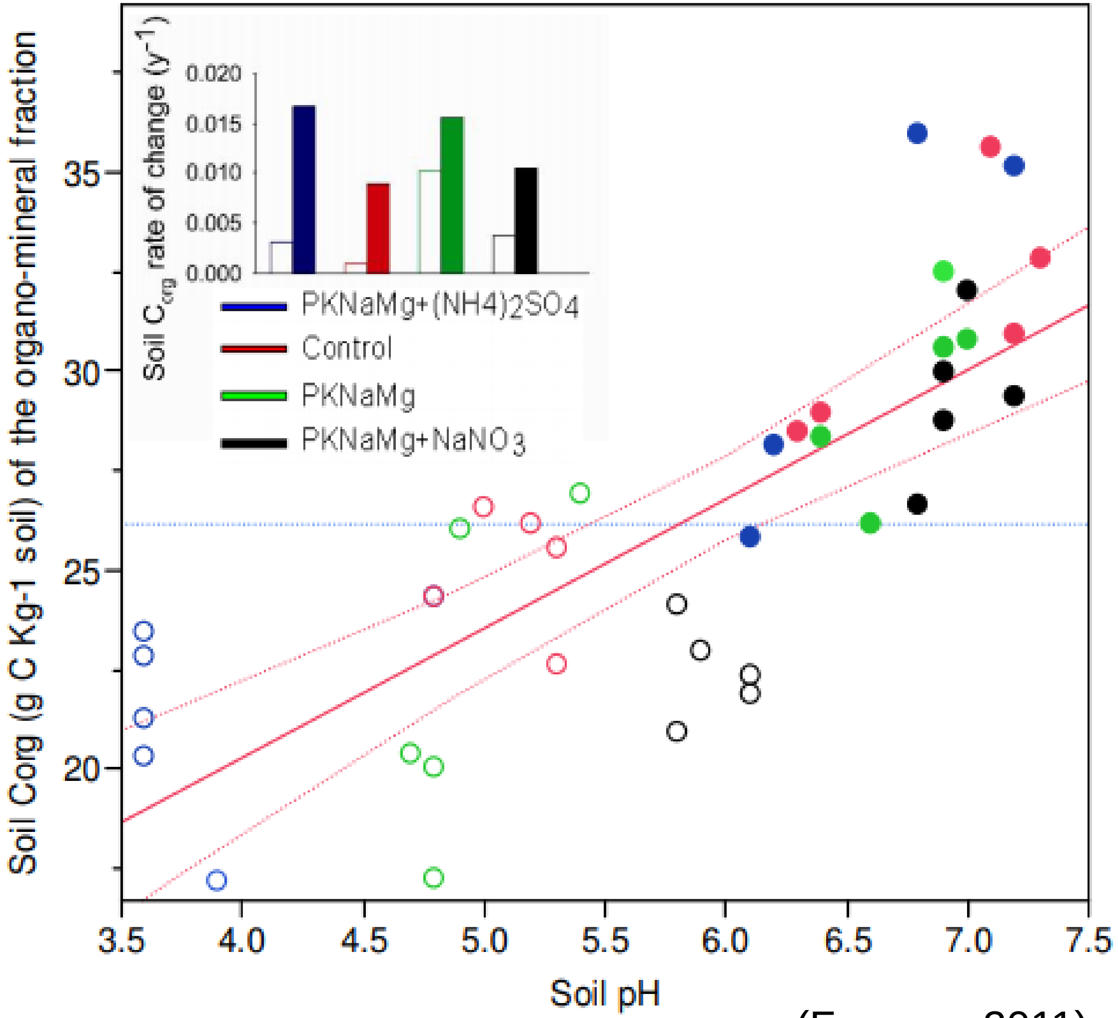
Improving carbon efficiency in dairy systems: Grassland management

- Carbon sequestration, impact of:
    - Liming
    - Reseeding
    - Fertiliser addition

AGRI-FOOD
& BIOSCIENCES
INSTITUTE

Carbon sequestration: the importance of pH

- Positive relationship between soil pH and carbon sequestration:
  - Increased microbial activity
  - Long-term studies show SOC increases 2 – 20 times
- Opportunity to improve soil pH content in NI soils



(Fornara, 2011)

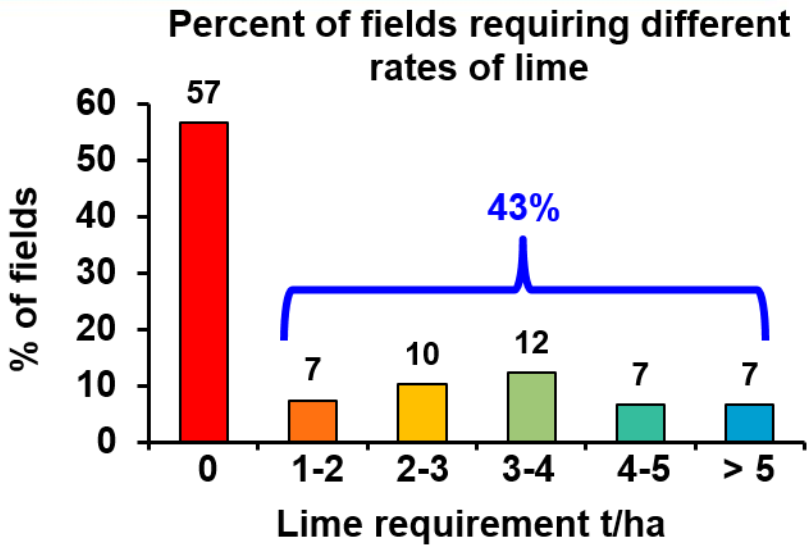
AGRI-FOOD & BIOSCIENCES INSTITUTE

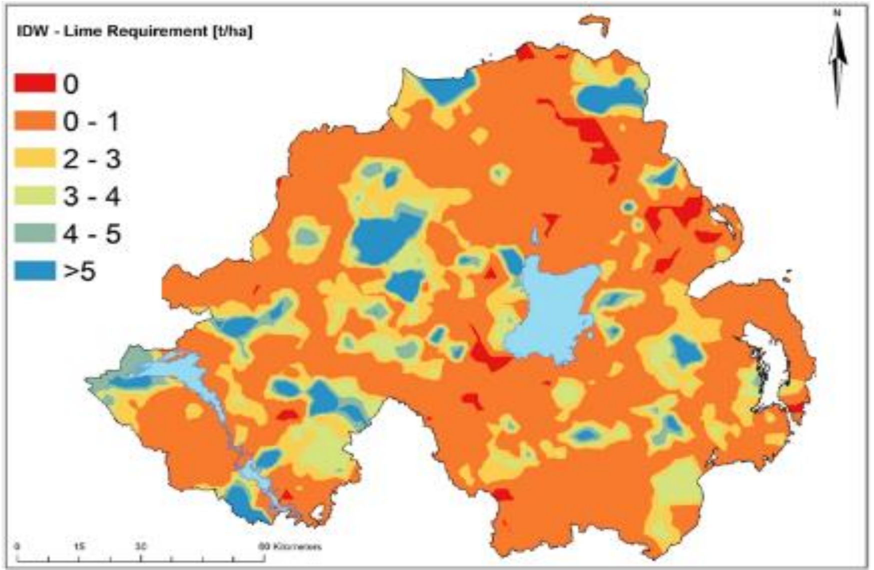
Carbon sequestration: the importance of pH

- AFBI research to better understand, protect and enhance soil fertility to deliver high levels of grass growth whilst using nutrients efficiently

- **Overall 43% of 805,000 ha grassland** ***(excluding rough grazing – peaty land)*** **requires lime**

- **Extra grass represents an almost 5 fold return on the lime investment**

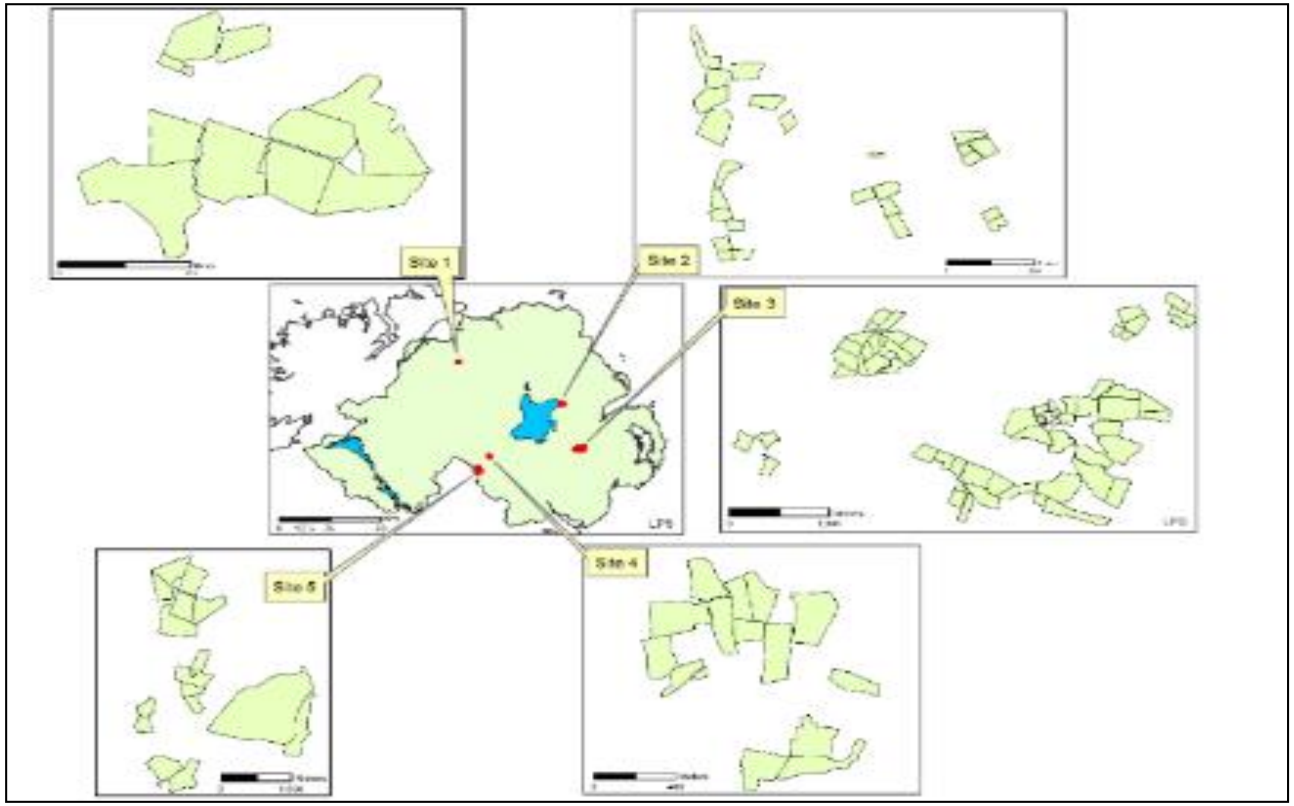


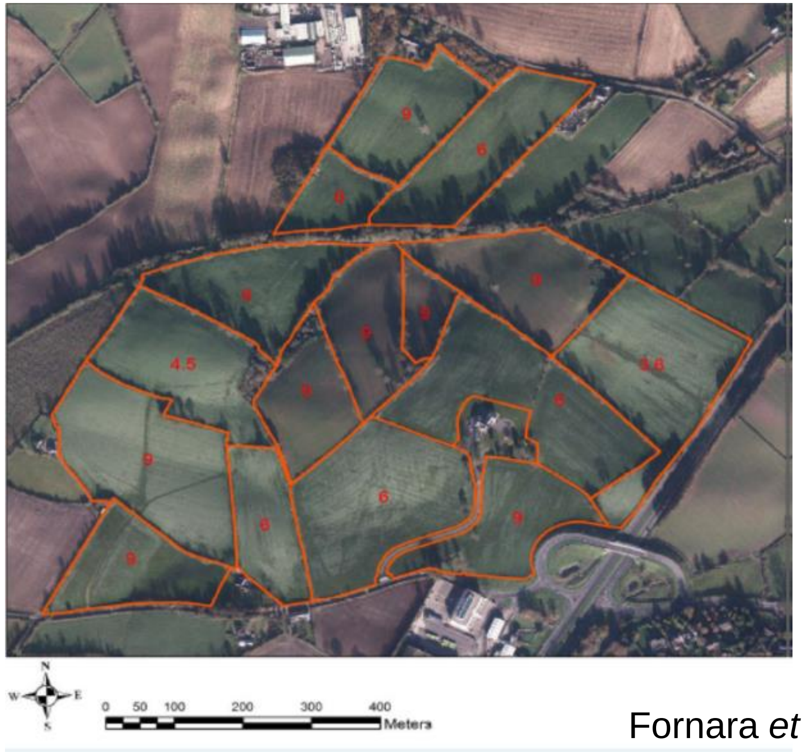


AGRI-FOOD & BIOSCIENCES INSTITUTE

Carbon sequestration: the impact of reseeding

- Obtain field records for 126 sites across N.I. from commercial farms
- All receiving >150kg N/ha
- Number of reseeding events identified for last 50 years

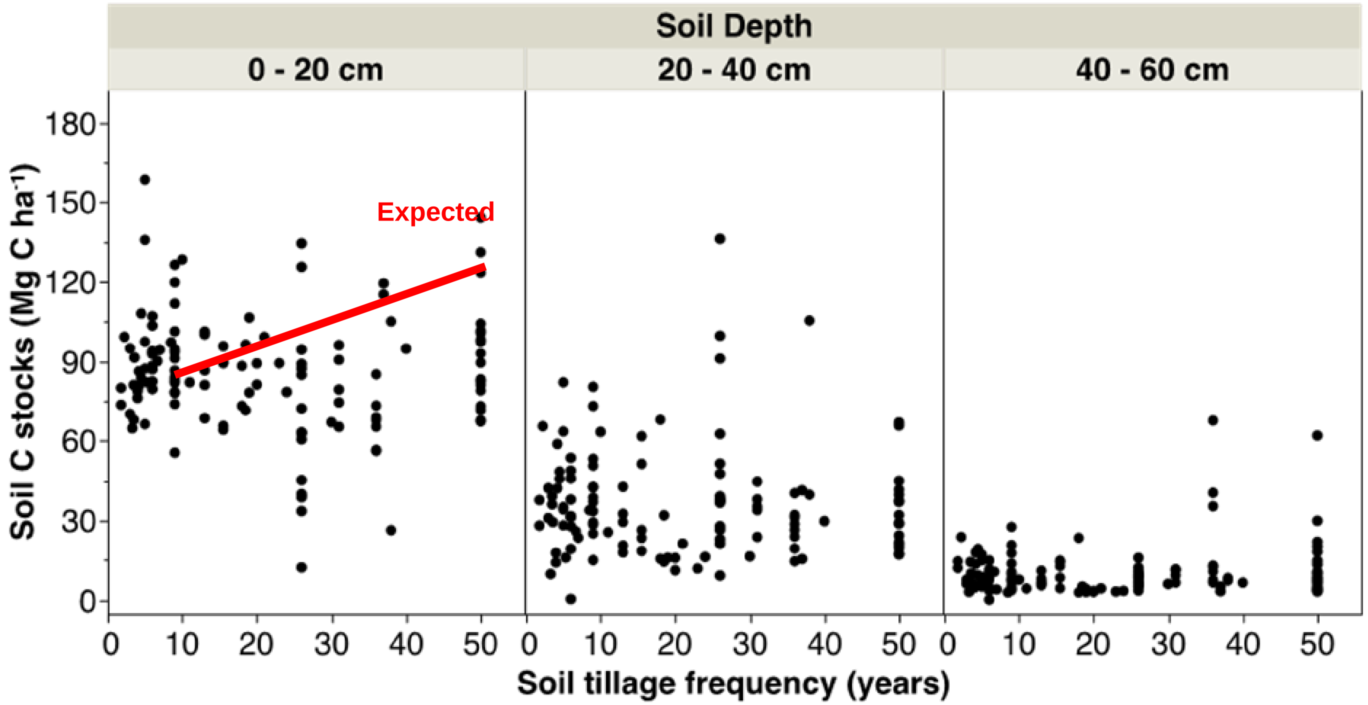




Fornara *et al. Under review*

Carbon sequestration: the impact of reseeding

- Most carbon stored in top 20cm of soil
- **No negative impact** of reseeding on soil carbon stores
- Short term increases in respiration offset by long-term increases in microbial biomass
- Further sites needed!



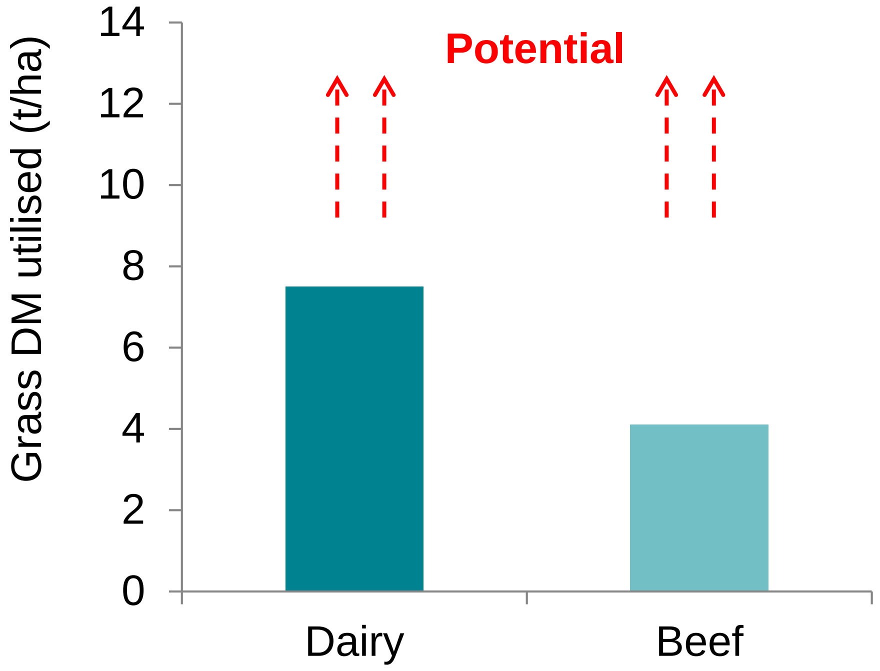
AGRI-FOOD & BIOSCIENCES INSTITUTE

Fornara *et al*. *Under review*

Carbon sequestration: the role of productive grasslands

- Nitrogen is essential to bind C in the soil
- Nutrient amendments associated with increased C sequestration (long-term slurry experiment)
- 1985 – 1998, increased fertiliser N:
    - 144 → 240kg N/ha = + 9% SOC
    - 96 → 228kg N/ha = +14% SOC

Estimated grass utilisation on NI farms (Mayne and Bailey, 2016)



Significant potential to increase productivity of N.I. grasslands

AGRI-FOOD & BIOSCIENCES INSTITUTE

GrassCheck NI: Grass growth and quality monitoring

- Established in 1998 – 20 years of continuous data
- Grass growth and quality monitoring project
- Weekly monitoring of two core locations:

  CAFRE, Greenmount

  AFBI, Hillsborough
- Plot management replicates intensive dairy grazing – 21-day rotation
- Long-term weather records
- Weekly herbage mass and quality measurements
- Grass growth forecasts published throughout the grazing season

GrassCheck NI

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

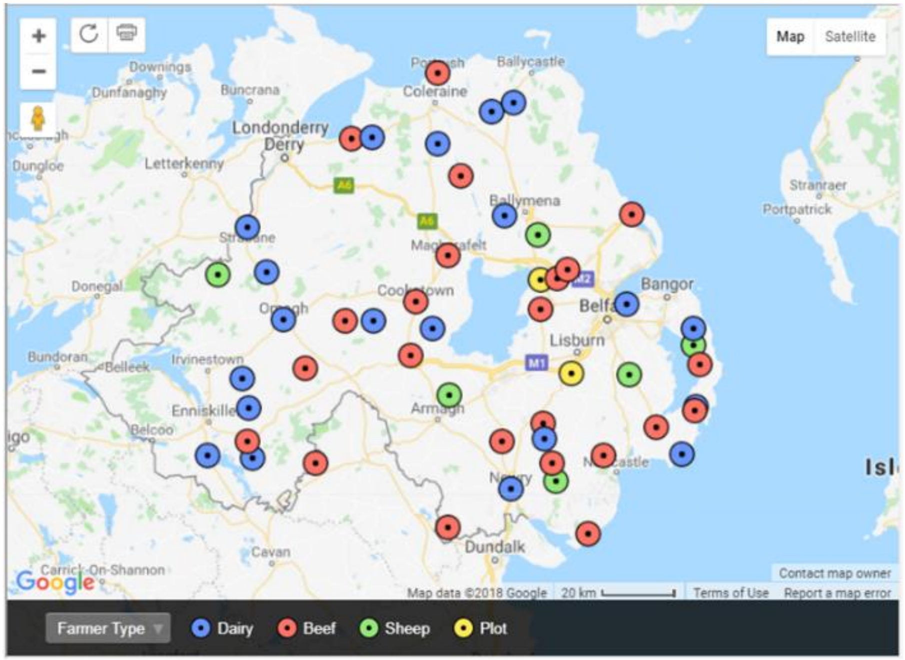
Department of Agriculture, Environment and Rural Affairs www.daera-ni.gov.uk

CIEL Centre for Innovation Excellence in Livestock

cafre College of Agriculture, Food & Rural Enterprise

GrassCheck NI: On-farm monitoring network

- 2017: GrassCheck expanded to include data recording of grass growth and grassland management on commercial farms
- Since 2018 - 48 dairy, beef and sheep farmers
- Range of:
  - production systems
  - land type
  - growth potential
  - management intensity



AGRI-FOOD & BIOSCIENCES INSTITUTE

GrassCheck NI: On-farm monitoring network

- **Research aims:**
  - Provide detailed understanding of grass growth potential across Northern Ireland
  - Identify actual variability in grass production and quality on commercial farms
  - Provide core evidence base for policy on the grassland productivity of Northern Ireland farms

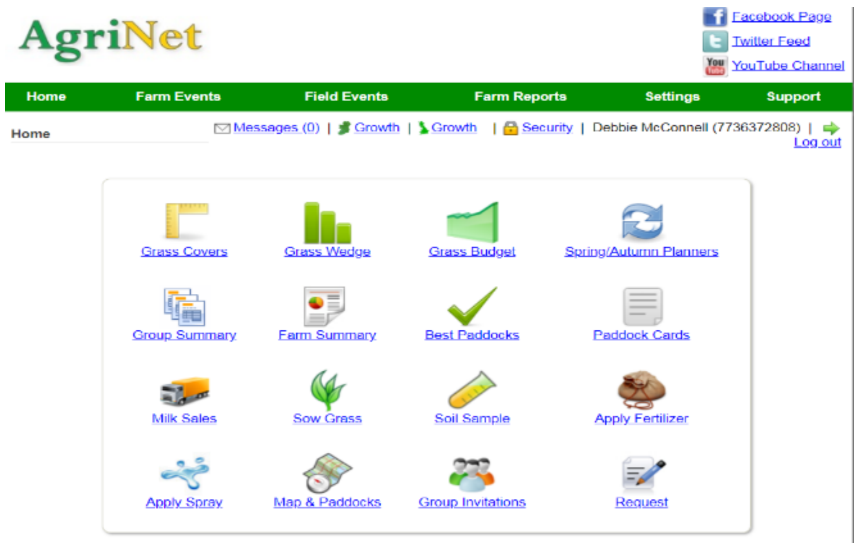
- **Knowledge exchange benefit:**
  - Provides weekly bulletin to assist farmers in grassland management decisions
  - 7- and 14-days predictions of grass growth to aid planning for grazing/grass-based systems

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

GrassCheck NI: On-farm monitoring network

Data recording

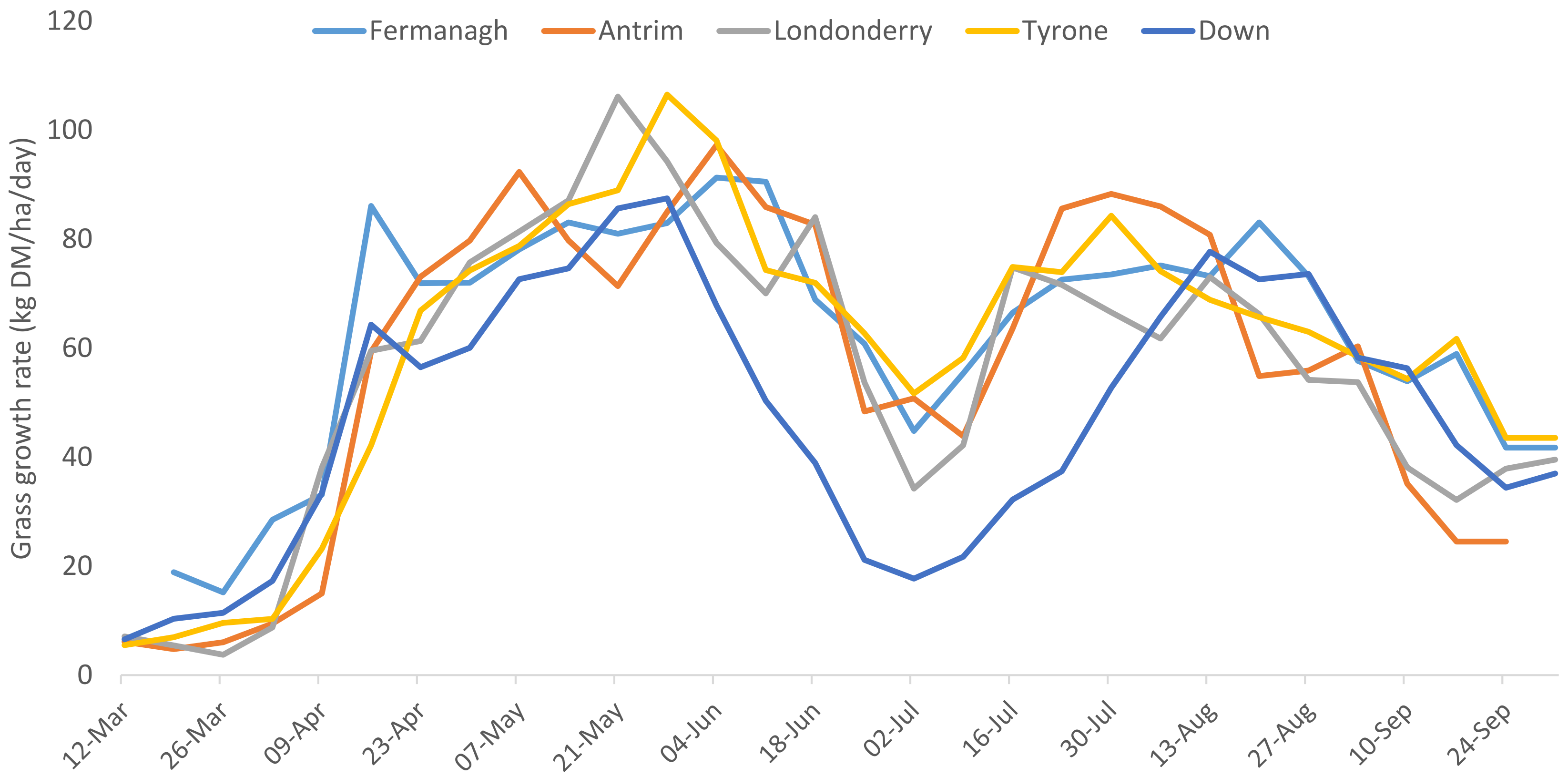
- Automated weather stations
  - 30 minute intervals, includes soil moisture/temp
- Weekly grass quality
- Weekly grass growth
- Stocking rates
- Grazing events and grass utilisation
- Reseeding, soil and nutrient management
- Annual summary data - paddock-by-paddock grass performance



AGRI-FOOD & BIOSCIENCES INSTITUTE

GrassCheck NI: On-farm monitoring network

- 2018 Grass growth curve by county for GrassCheck dairy farms



AGRI-FOOD & BIOSCIENCES INSTITUTE

GrassCheck NI: On-farm monitoring network

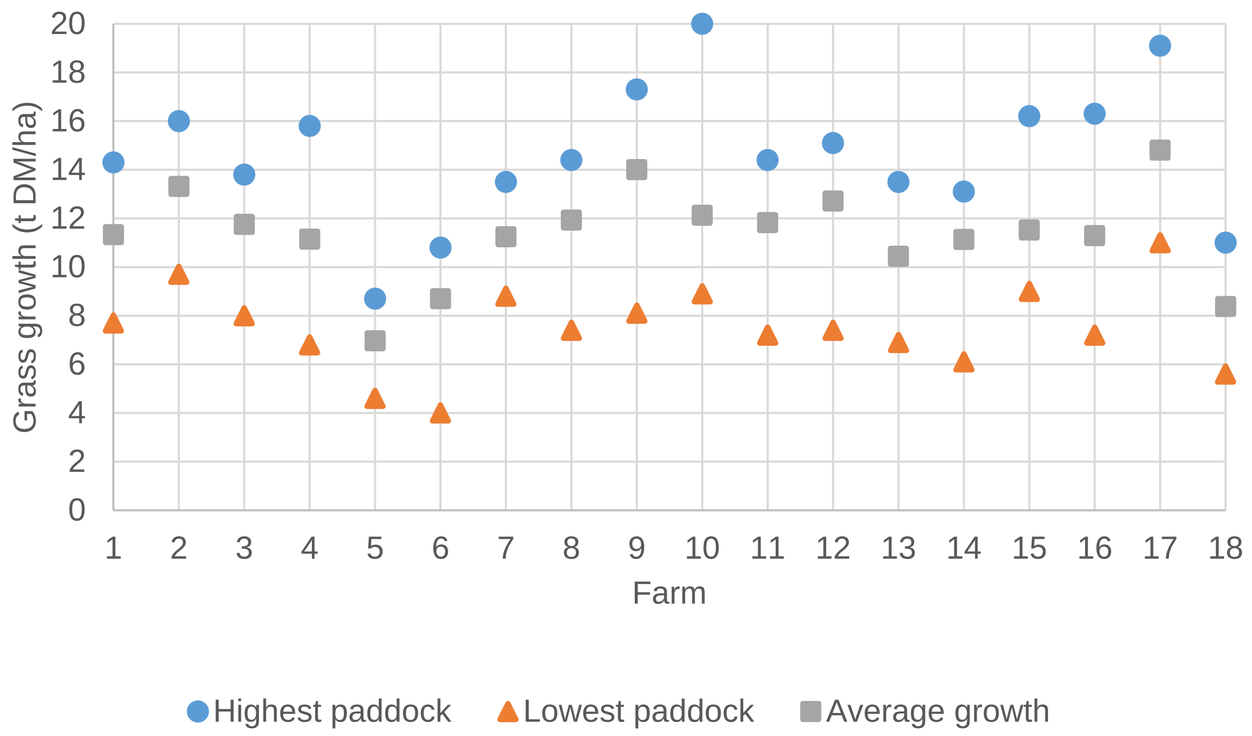
- 2018 Monthly grass growth (t DM/ha) by county on dairy farms

	Antrim	Down	Fermanagh	Londonderry	Tyrone
March	0.2	0.3	0.4	0.2	0.2
April	1.6	1.5	1.9	1.7	1.5
May	2.6	2.4	2.5	2.8	2.8
June	2.2	1.1	2.1	1.9	2.1
July	2.2	1.1	2.0	1.9	2.2
August	2.1	2.2	2.3	1.9	2.1
September	0.8	1.3	1.5	1.2	1.6
Total	**11.6**	**10.0**	**12.8**	**11.6**	**12.4**

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

GrassCheck NI: On-farm monitoring network

Average, highest and lowest growth fields for GrassCheck dairy farms during 2018



Variation between highest and lowest growth paddocks = **7.2t DM/ha**

Feed value lost = £974/ha

Grass measurement key to identifying poor performing areas

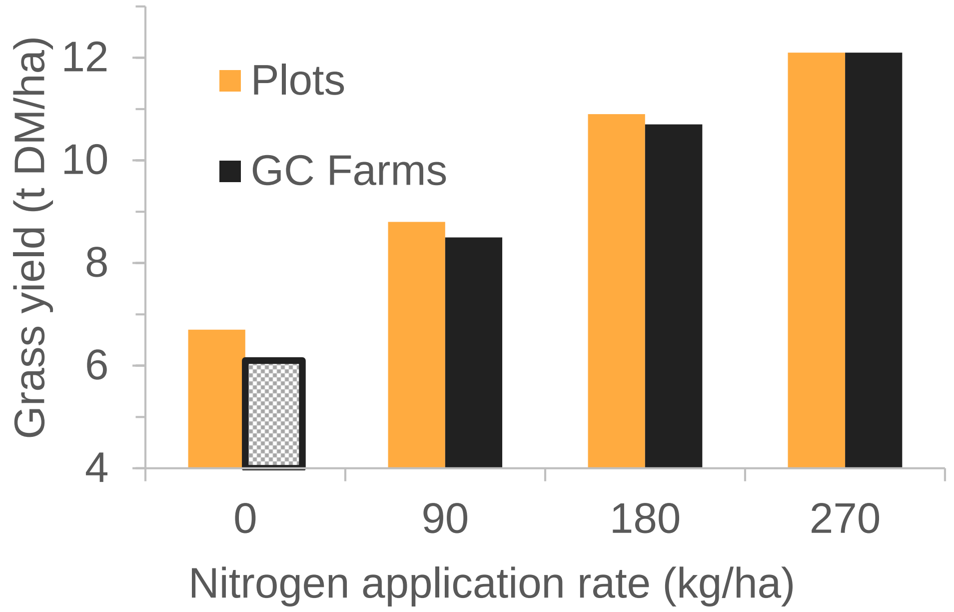
AGRI-FOOD & BIOSCIENCES INSTITUTE

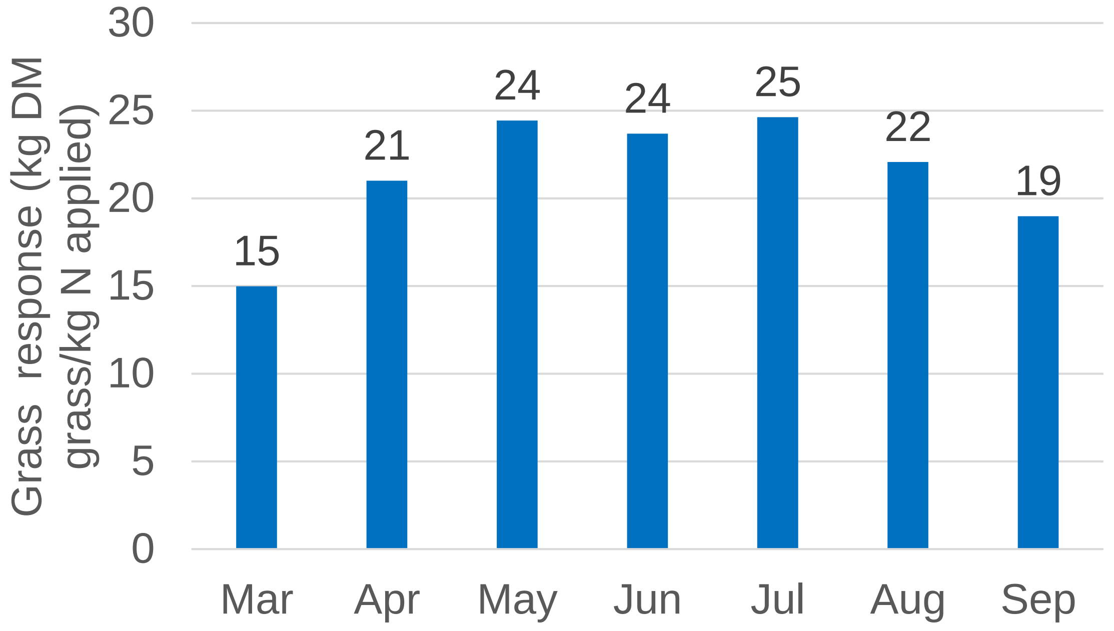
GrassCheck NI: Nitrogen management

- Nitrogen fertiliser application currently c. 150kg N/ha
- 1kg N fertiliser @ £0.8/kg delivers:

  21kg DM grass @ £0.136/kg = £2.86

  - Return on Investment = **3.6:1**





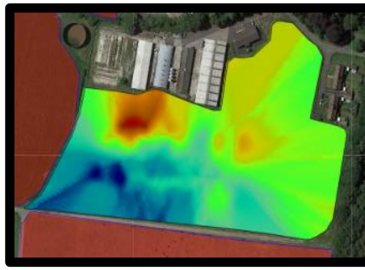
AFBI Precision Grassland Platform

A connected landscape integrating soil, plant, animal and climate data to improve our understanding and management of grasslands

Platform infrastructure:

- Coverage of dairy and beef systems (78ha)
- Soil, NDVI, Satellite, Lidar, animal based data feeds
- **GPS soil analysis, fertiliser and slurry application**
- In-field animal monitoring: rumination, activity, concentrate feed stations
- Live streams of data to online platform for rapid decision making for grassland management
- Integration of soil, plant, animal and climate data on one platform

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE



Improving carbon efficiency in dairy systems

Grassland

C sequestration, N2O emissions

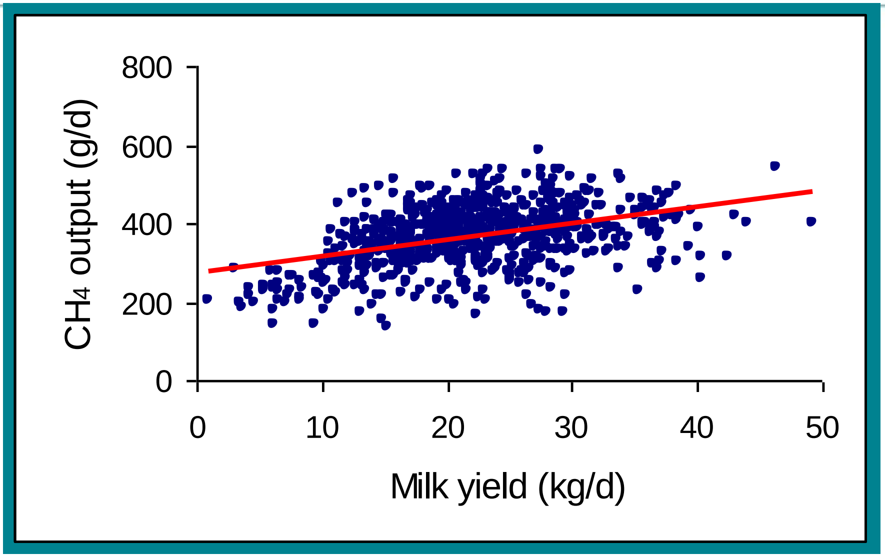
Animal

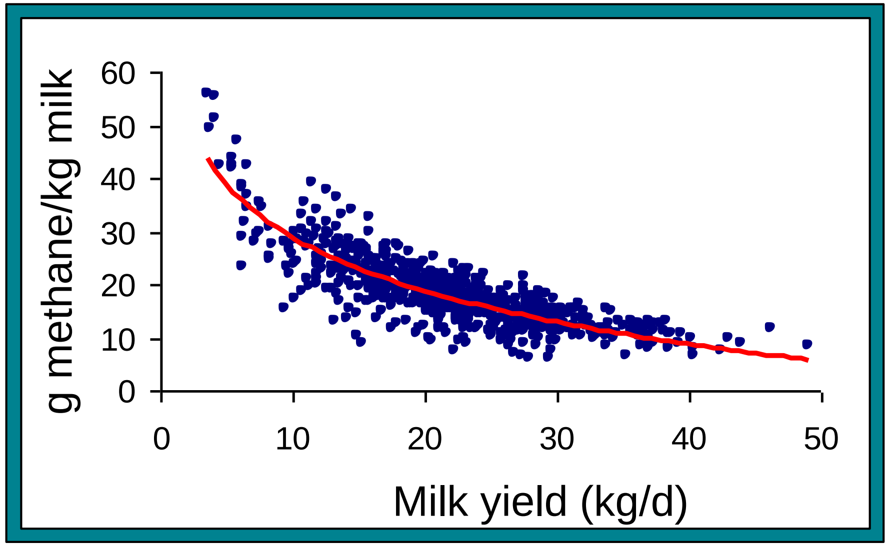
Enteric methane emissions

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

AFBI research on CH_4 emissions from ruminants

- Large animal respiration calorimeters installed at AFBI in 1993, and over 1500 animals subject to 'energy metabolism' measurements
- Provided a huge data base on CH_4 production from a wide range of animals types, physiological stages and diets
- Data has been extensively mined and key drivers of CH_4 production identified for 'indoor diets'



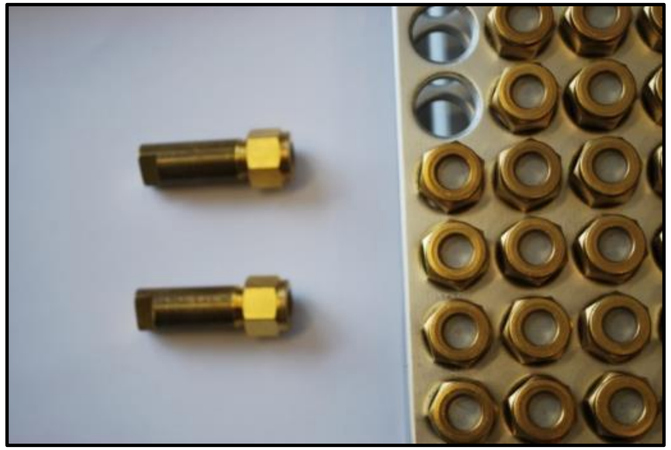


AGRI-FOOD & BIOSCIENCES INSTITUTE

Measuring CH4 production at AFBI

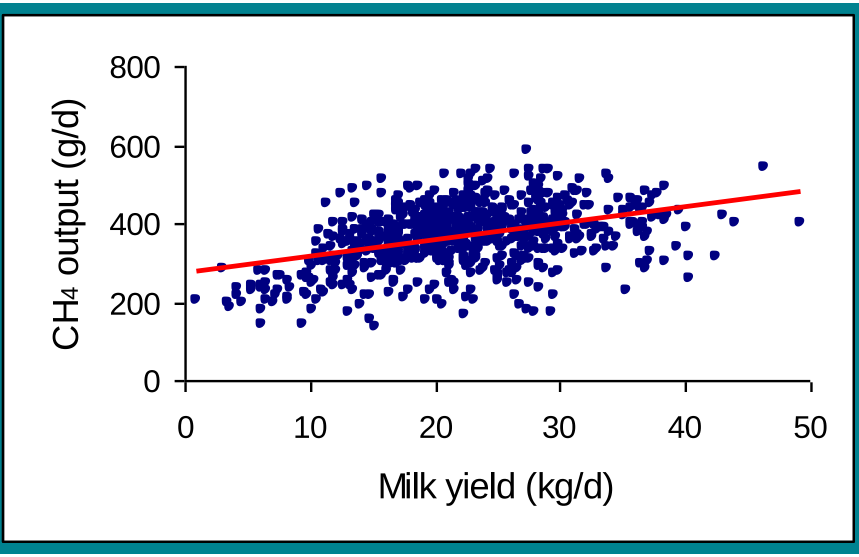
Large and small animal respiration calorimeters

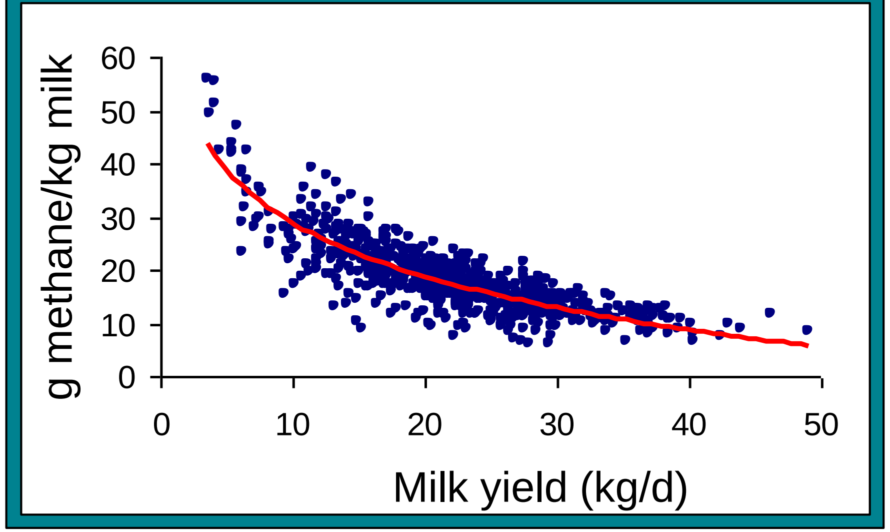
SF_6 technique to measure CH4 production from grazing livestock



AFBI research on CH_4 emissions from ruminants

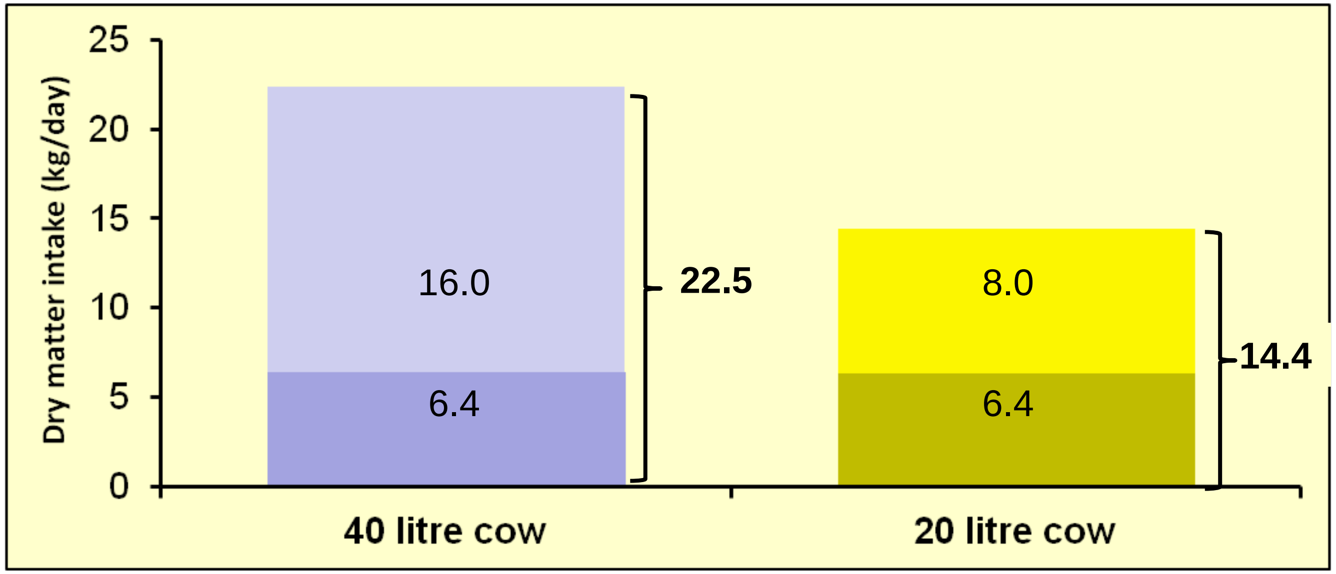
- Large animal respiration calorimeters installed at AFBI in 1993, and over 1500 animals subject to ‘energy metabolism’ measurements
- Provided a huge data base on CH_4 production from a wide range of animals types, physiological stages and diets
- Established strong link between milk yield and C efficiency
- Limited impact of either system or breed type on C efficiency





AGRI-FOOD
& BIOSCIENCES
INSTITUTE

Why does methane production per litre of milk decrease with higher milk yields?



448 g CH_4/day
(28% due to maintenance)

11.2 g CH_4/litre milk

288 g CH_4/day
(44% due to maintenance)

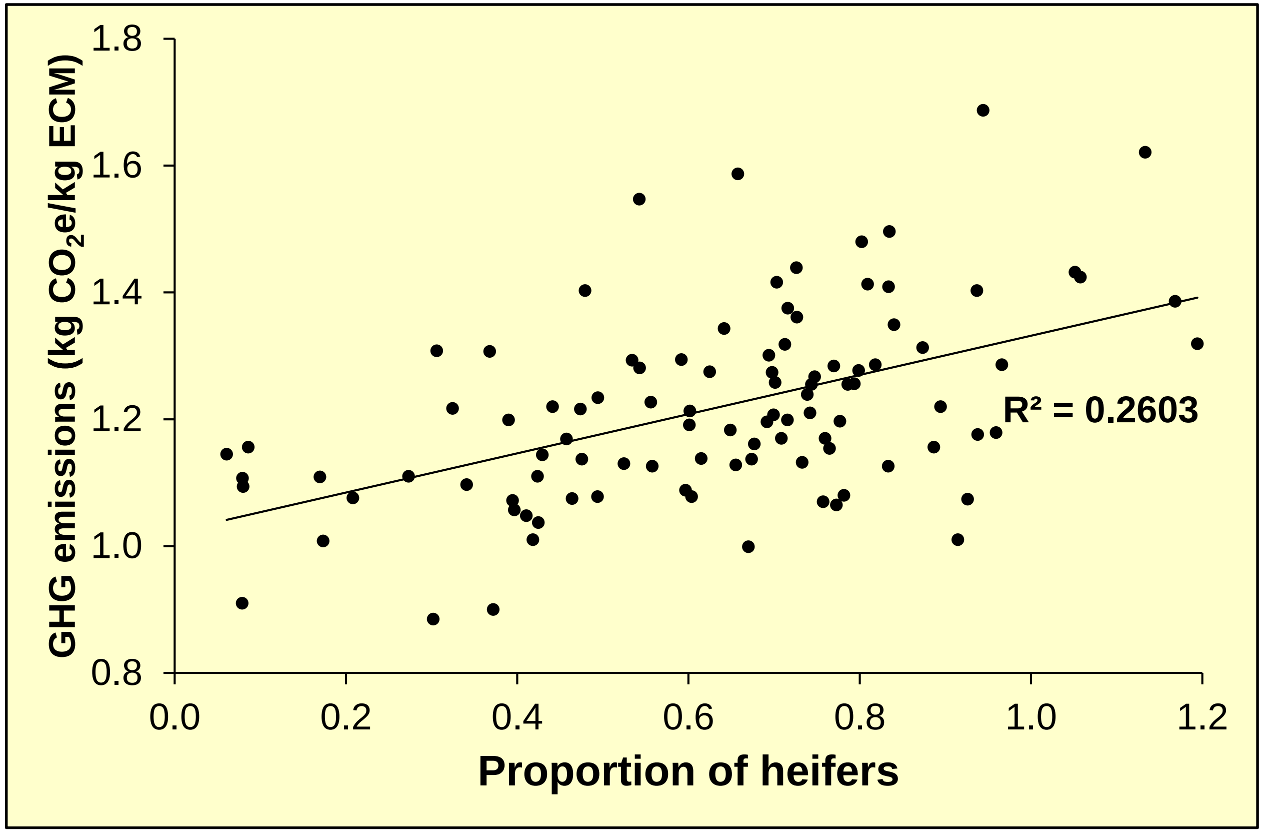
14.4 g CH_4/litre milk

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

Factors affecting carbon efficiency in dairy production systems

Functional traits equally important as poor performance in these areas can lead to:

- Increased number of heifers on the farm
- Cows not achieving their mature milk yield potential



Relationship between GHG emissions/kg of ECM milk and the proportion of heifers on a farm (100 farms)

(Ferris 2014)

AGRI-FOOD & BIOSCIENCES INSTITUTE

GHG associated with heifer rearing

Birth

12 months

24 months

?

36 months

GHG associated with heifer rearing
to 24 months approximately
4200 kg $CO_2{}^{e}$/heifer

23% of emissions on average Northern Ireland systems are due to heifer rearing

AGRI-FOOD
& BIOSCIENCES
INSTITUTE

Effect of replacement rate and age at first calving on total GHG production

	Scenario 1	Scenario 2	Scenario 3
Replacement rate (%)	15	30	30
Age 1st calving (months)	24	24	36
Number of replaced heifers on farms	30	60	90
GHG associated with heifer rearing/year (kg CO_2 equivalent)	60, 000	120, 000	315, 000

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

Effect of improving fertility on GHG emissions from dairy systems

Current level		Ideal level	
Days to 1st AI	= 78	Days to 1st AI	= 70
Oestrous detection rate	= 50%	Oestrous detection rate	= 70%
Conception to 1st AI	= 38%	Conception to 1st AI	= 65%
Conception to subsequent AI	= 37%	Conception to subsequent AI	= 60%

Improving fertility would reduce which farm methane emissions by 24%

Garnsworthy *et al*, 2004

Any strategy which will improve longevity, without reducing cow performance, will reduce both methane and nitrous oxide emissions

Use of indices such as £PLI (United Kingdom) will allow cows with good functional performance to be selected

AGRI-FOOD & BIOSCIENCES INSTITUTE

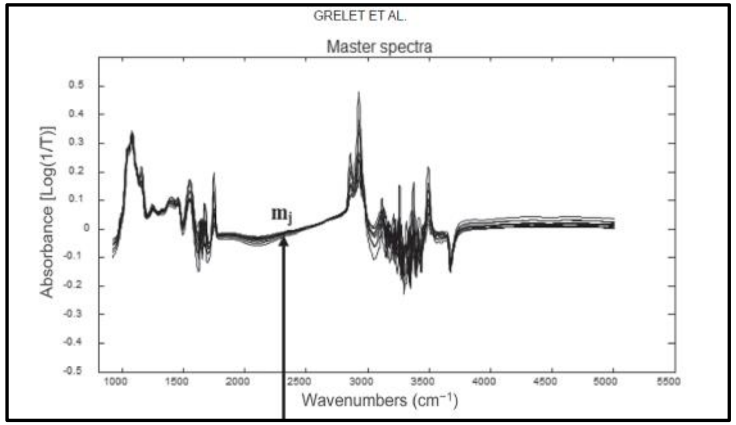
C efficiency on-going work

1. Dietary additives:
    - ‘Biological additives’: eg probiotics
    - ‘novel plants’: eg essential oils, seaweeds,

2. Improved diet quality

3. Genetic selection:
    - Higher performing animals (lower production per unit product)
    - More efficient animals (high ‘residual feed intakes’)
    - Genetically low CH4 emitters

Genotype plus Environment
Integration for a more sustainable dairy production system



AGRI-FOOD & BIOSCIENCES INSTITUTE

Summary

- Considerable improvements have been made in C efficiency in NI farms in the last few decades

- N.I. grasslands have a key role to play in sequestering carbon and good grassland management practices will help achieve this:
  - Liming
  - Reseeding
  - Targeted nutrient use

- Improving technical efficiency on farm remains a key driver of C efficiency – targeting production and functional traits are essential

AGRI-FOOD & BIOSCIENCES INSTITUTE