The role of N-use efficiency in lowering nitrous oxide emissions

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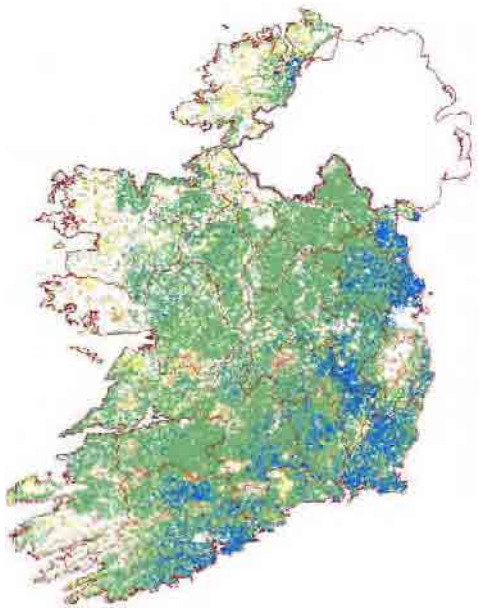
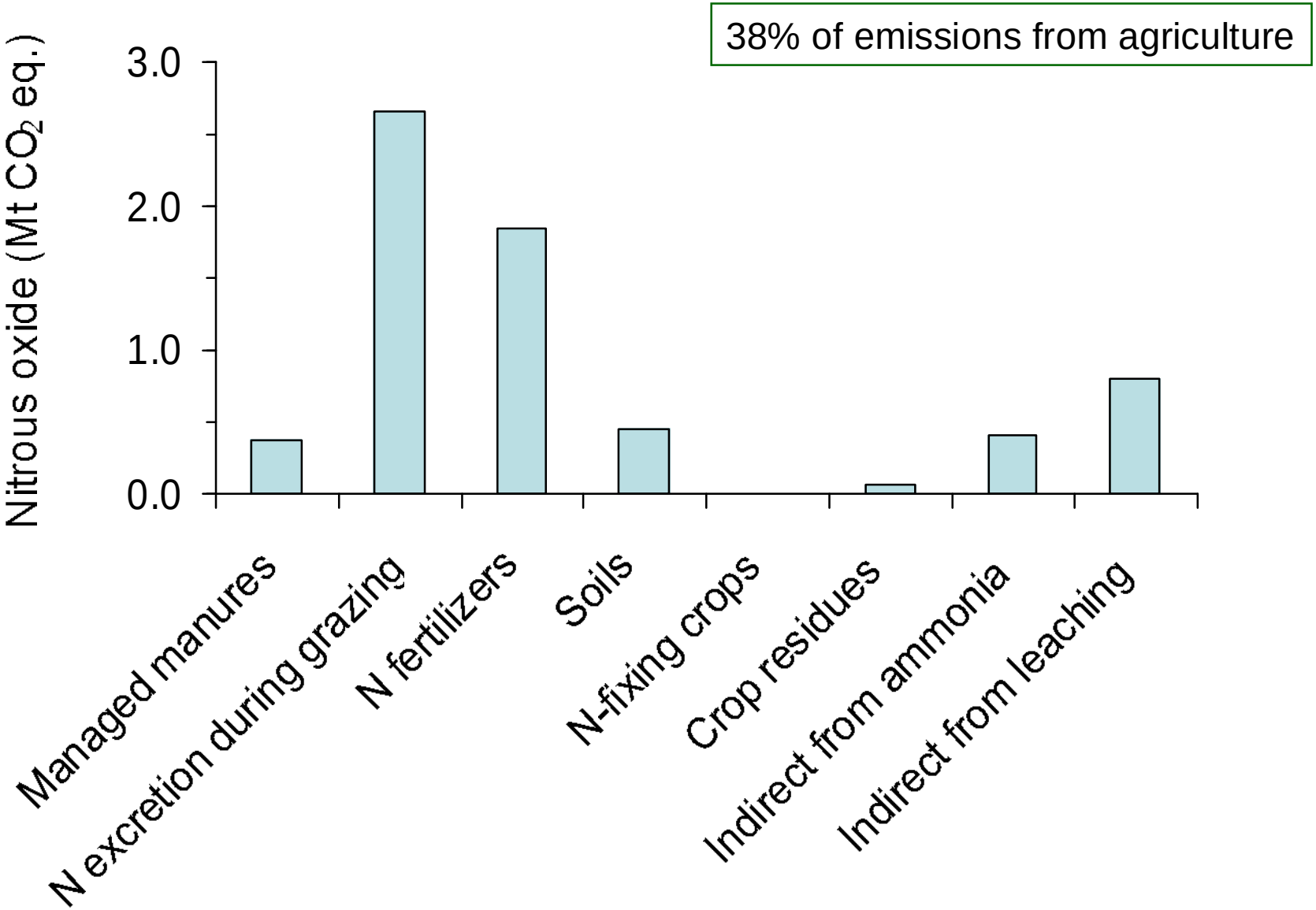


Introduction and overview

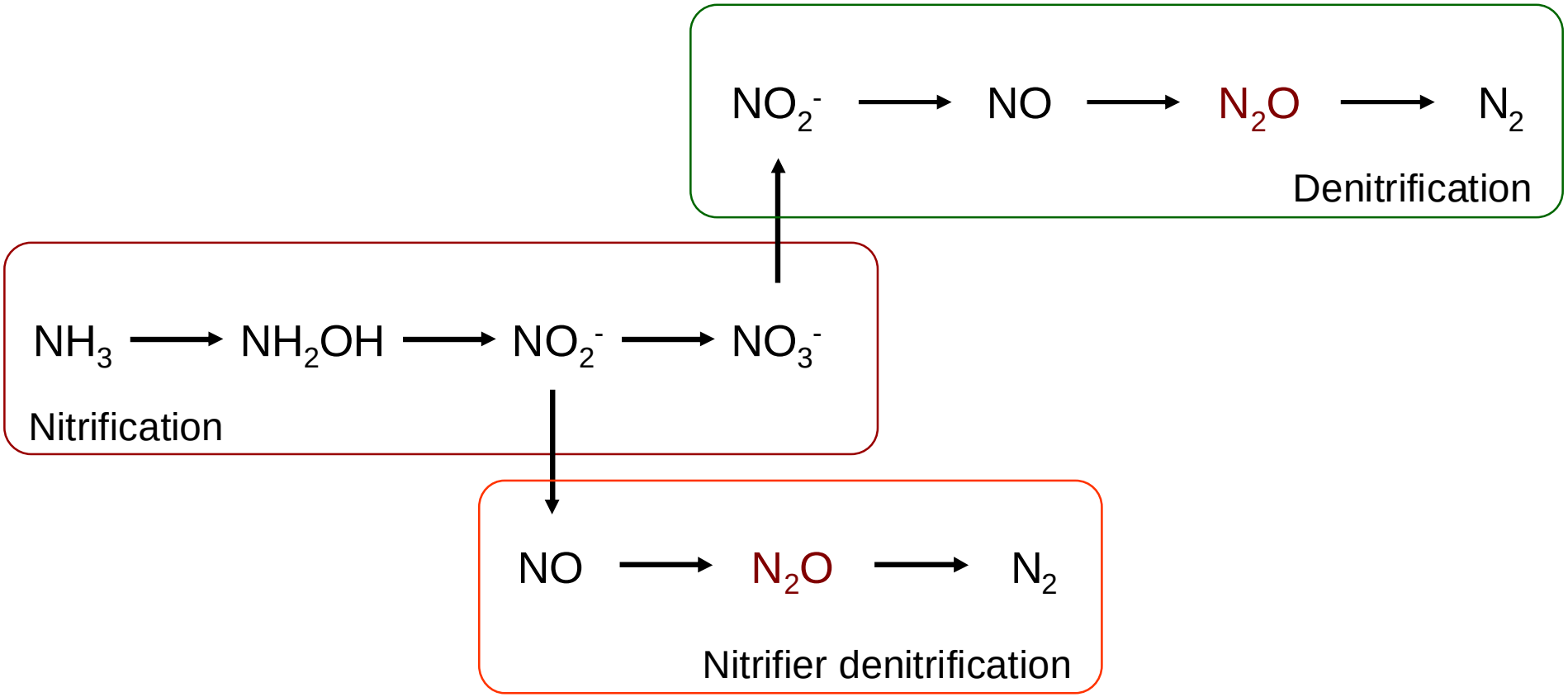
- Sources of N_2O from Irish agriculture
- Grassland 90% of agricultural area - scale of solution
- The process of denitrification and N_2O losses
- N-use efficiency
- Options
  - nitrification inhibitors
  - slurry application with trailing shoe, injection
  - White clover
- Conclusions

Sources of nitrous oxide emissions from agriculture 2008

(McGettigan *et al*., 2010)



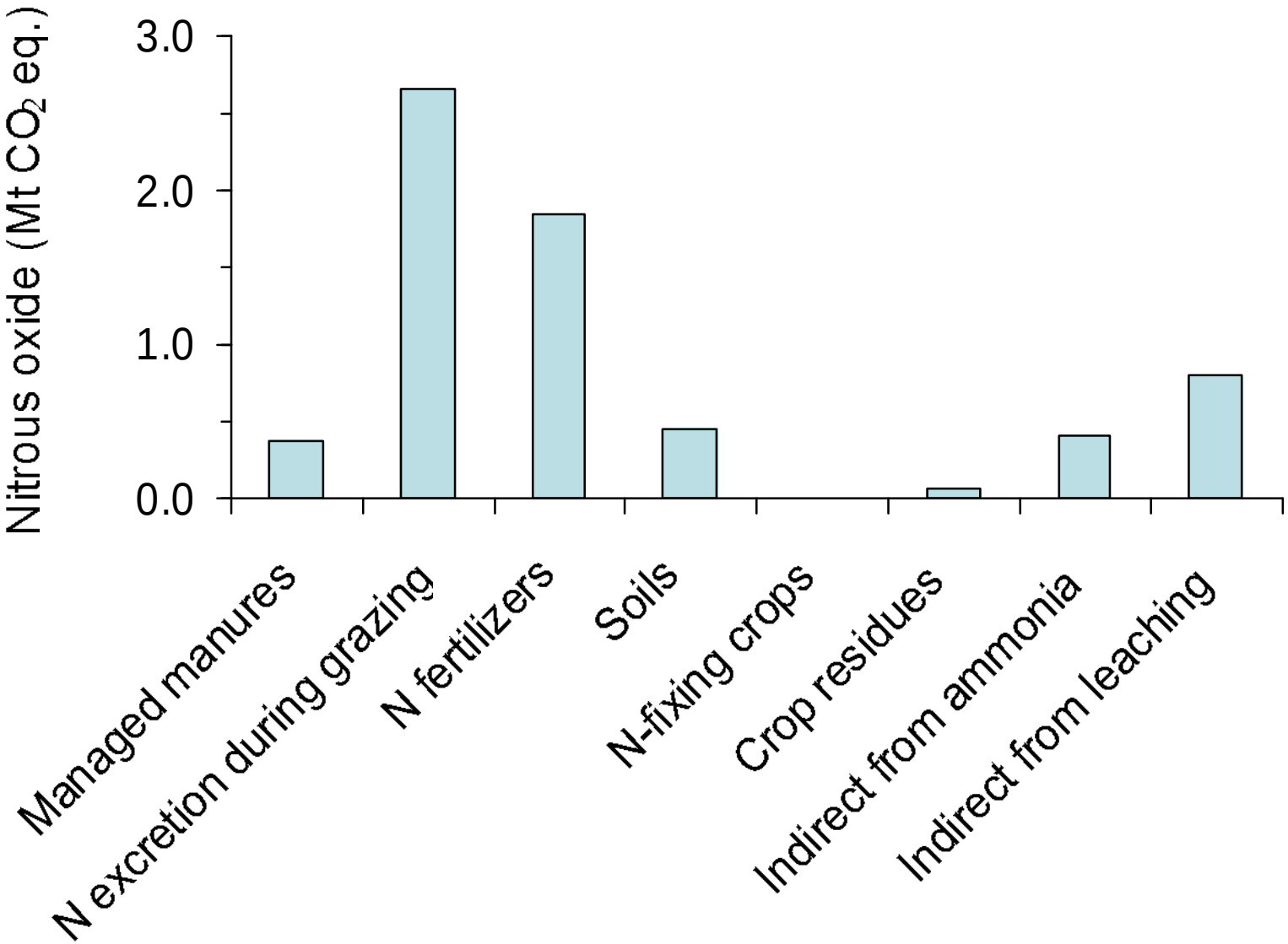
Nitrification and Denitrification



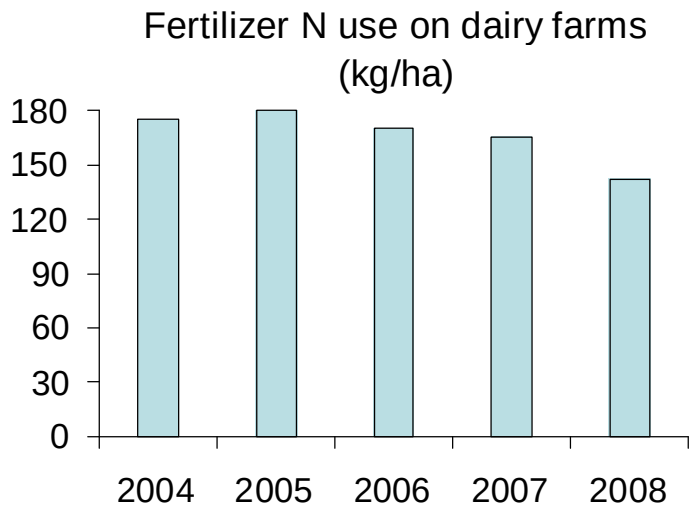

Soil is an important source of N for plant uptake

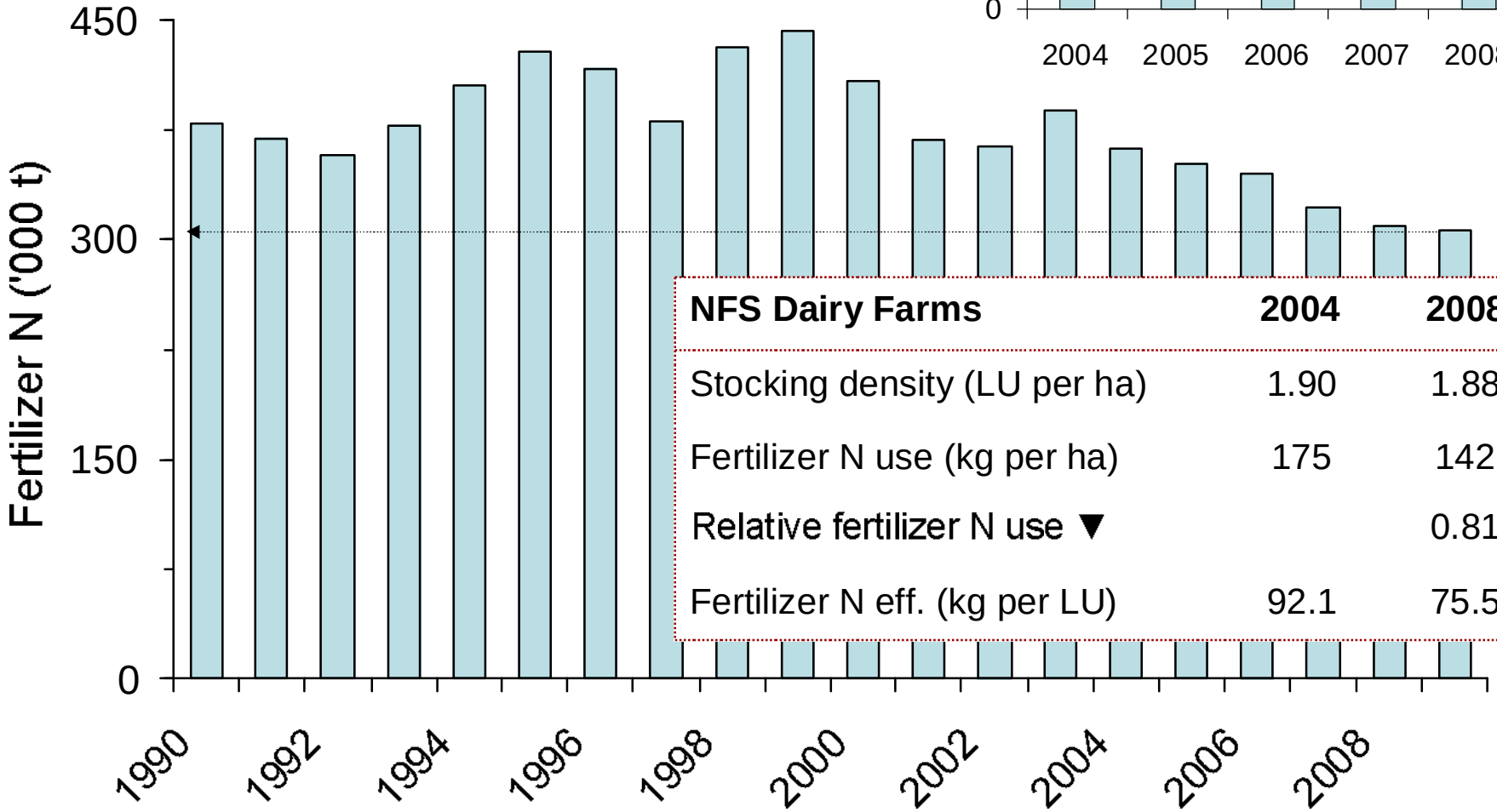
Sources of nitrous oxide emissions from agriculture 2008

(McGettigan *et al*., 2010)



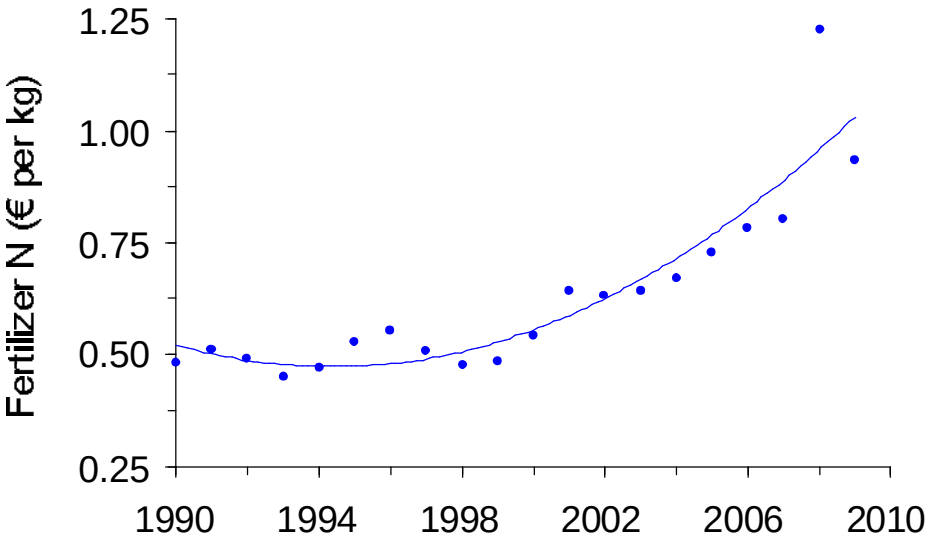
National fertilizer N use



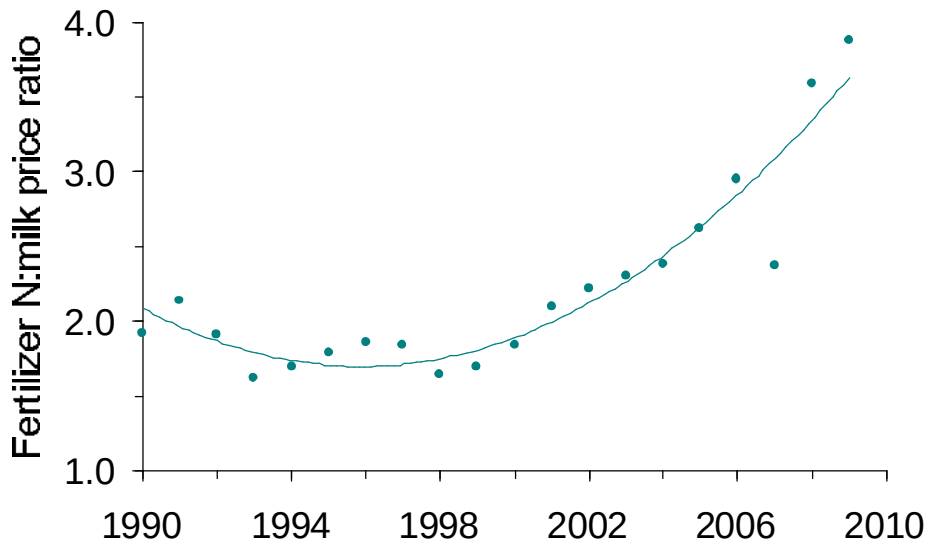


NFS Dairy Farms	2004	2008
Stocking density (LU per ha)	1.90	1.88
Fertilizer N use (kg per ha)	175	142
Relative fertilizer N use ▼		0.81
Fertilizer N eff. (kg per LU)	92.1	75.5

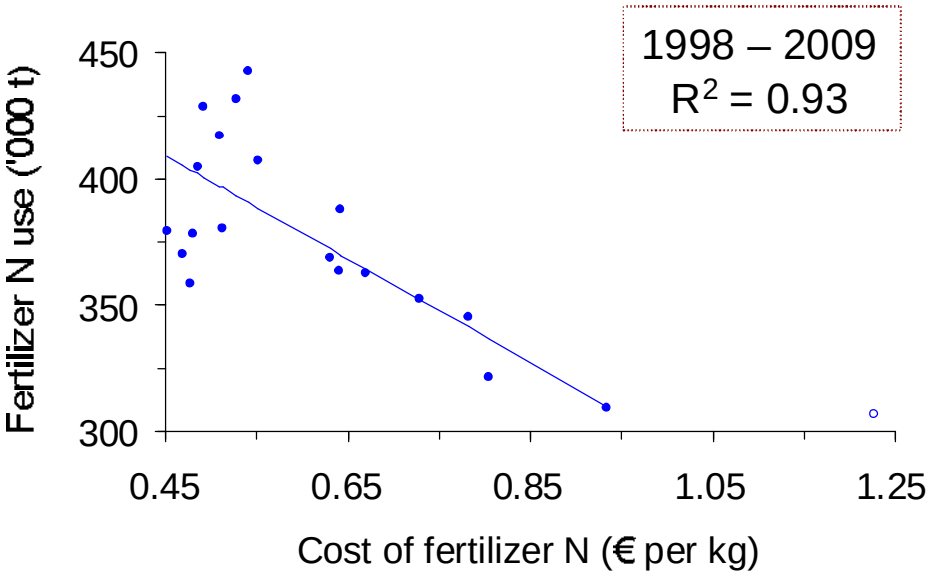
Cost of fertilizer N (€ per kg) 1990 - 2009



Fertilizer N:milk price ratio 1990 - 2009



Fertilizer N costs and national use



National fertilizer N use

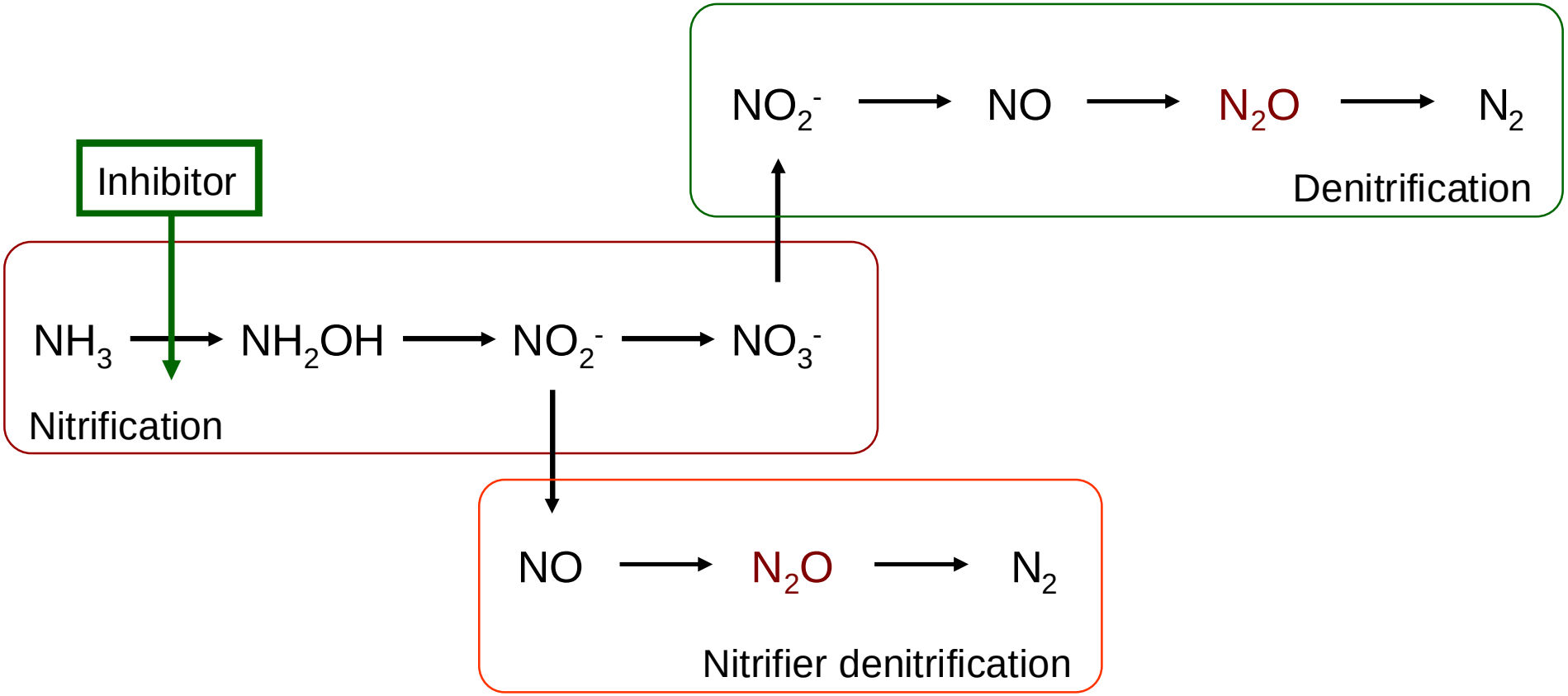
- Closely related to fertilizer N cost
- Projected ▲ in fertiliser N cost
- Especially relative to product prices
- Anticipate ▼ in national fertilizer N use
- Associated ▼ in N_2O emissions
- Alternatives to fertilizer N

Making more efficient use of fertilizer N on farms

- Farm gate N balance: surplus of N in inputs minus outputs in products
- Typical range in N-use efficiency = 15 to 35%

- Increase the efficiency of recycling within the farm gate (Treacy *et al*., 2008)
- Avoid wasteful use imported fertilizers – wrong times, matching rates to req. etc.
- ▼ farm gate surplus by 1 kg N per t milk = 29 kg CO_2 eq. (Schils *et al*. 2006)

Nitrification and Denitrification: Nitrification inhibitors



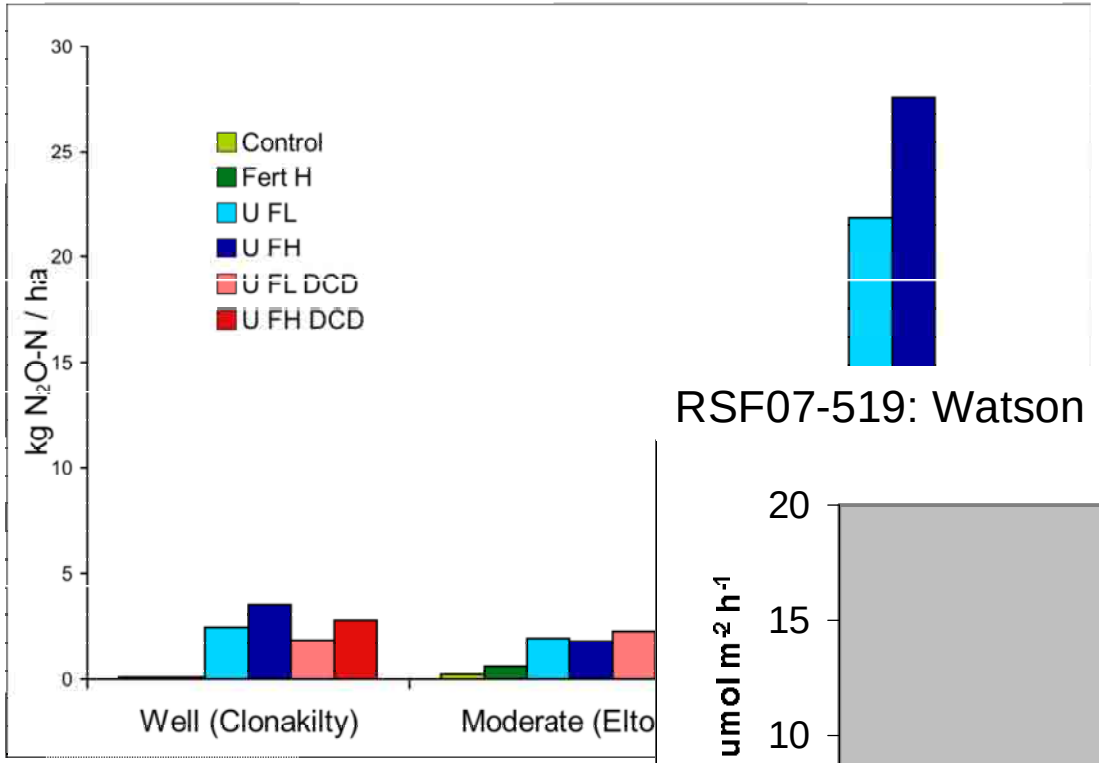
Inhibiting nitrification can lower N_2O emissions (and nitrate leaching)

Table 8: *Emissions of nitrous oxide after application of different nitrification inhibitors with different fertilisers.*

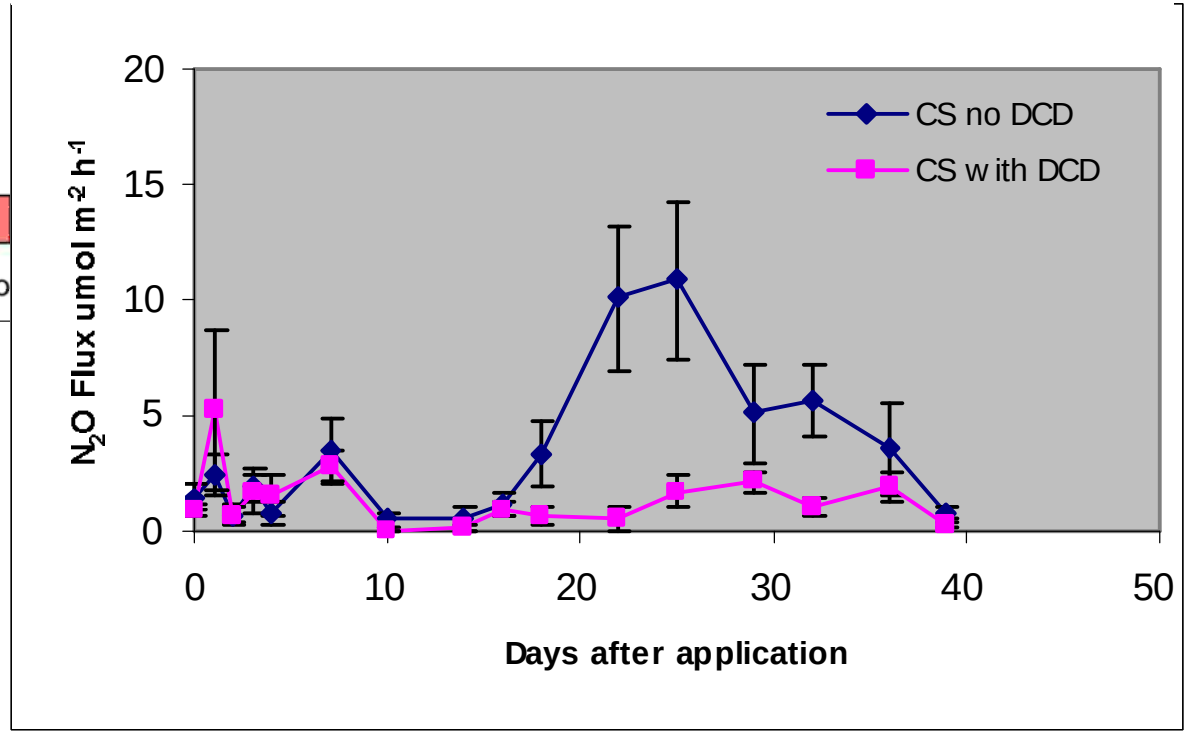
Nitrification inhibitor	Fertiliser	Country	Crop	Reduction of N_2O losses as %	Length of monitoring	Author
DMPP	Liquid cattle slurry	Spain	Clover/ryegrass	29	59 days	Menendez *et al.* (2006)
DMPP	Liquid cattle slurry	Spain	Pasture	69 48	106 days (autumn) 29 days (spring)	Merino *et al.* (2005)
DMPP	Ammonium sulphate nitrate Liquid cattle slurry	Spain	Grass	58 61	20 days 60 days	Macadam *et al.* (2003)
DMPP	Liquid cattle manure	UK	Grass	32	22 days	Dittert *et al.* (2001)
DMPP	Ammonium sulphate nitrate	Germany	Winter wheat	20	4 months	Linzmeier *et al.* (2001)
DMPP	Ammonium sulphate nitrate	Germany	Barley Maize Wheat	41 47 53	3 years	Weiske *et al.* (2001)
DCD			Barley Maize Wheat	30 22 29	3 years	
DCD	Urine	New Zealand	Grass	52 39 16.5	2-3 months (autumn) 2-3 months (spring) 2-3 months (summer)	Zaman *et al.* (2009)
DCD	Urea	New Zealand	Grass	75-91	2-3 months	Smith *et al.* (2008)
DCD	Urine	New Zealand	Grass	61-73	69-137 days	Di *et al.* (2007)
DCD	Urine	New Zealand	Grass	82	16 months	Di and Cameron, (2002)
DCD	Ammonium sulphate Urea	India	Rice	26 11	98 days	Kumar *et al.* (2000)
DCD	Urea	USA	Spring barley	82	90 days	Delgado & Mosier, 1996
DCD	Urine	Netherlands	Grass	50-89	14 days	DeKlein and van Logtestjin, (1994)
DCD	Ammonium sulphate	UK	grass	40	64 days	Skiba *et al.* (1993)
Nitrapyrin	Urea	USA	Corn	40-60	100 days	Bronson *et al.* 1992

DCD and N_2O emissions (RSF funded projects)

Dennis et al., 2008; Teagasc, Johnstown Castle



RSF07-519: Watson et al. unpub., AFBI, UCD, Teagasc



Nitrification inhibitors

- Nitrification inhibitors substantially lower emissions from fertilizer, slurry & urine
- Little or no improvement in agronomic performance (e.g. O'Conner et al., 2010)
- Costs associated with DCD exceed any economic benefit (Monaghan et al., 2009)
- No incentive for Irish farmers to use nitrification inhibitors at present

- Evidence of higher emissions from CAN compared with urea under damp conditions

Slurry application techniques

- Trailing shoe increases N-use efficiency and herbage production etc. compared with splash-plate (Lalor, 2008)
- Trailing shoe increases N_2O emissions because more N enters soil (less NH_3 lost)
- Need more fertilizer N with splash-plate for same level of productivity
- On balance – no benefit or detriment with trailing shoe for N_2O emissions (Huijsmans and Schils, 2009)

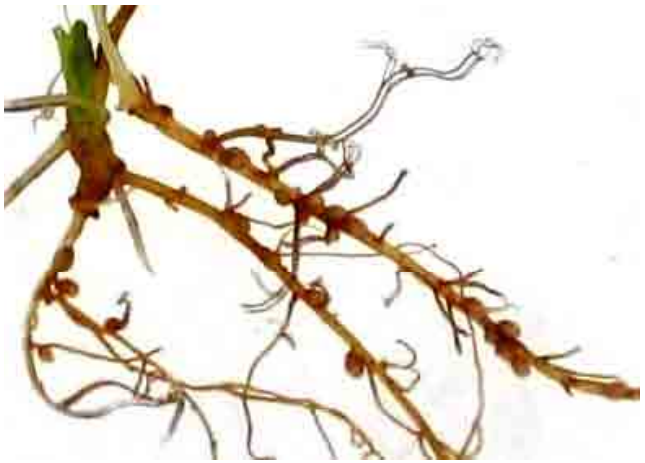


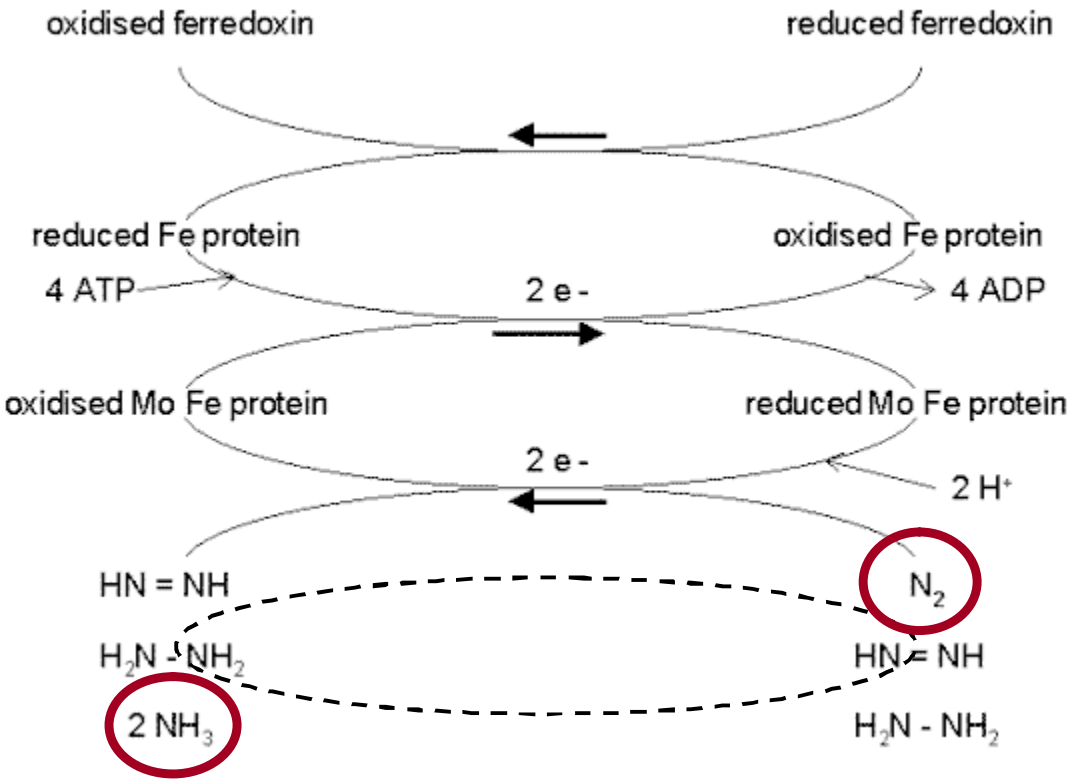

White clover

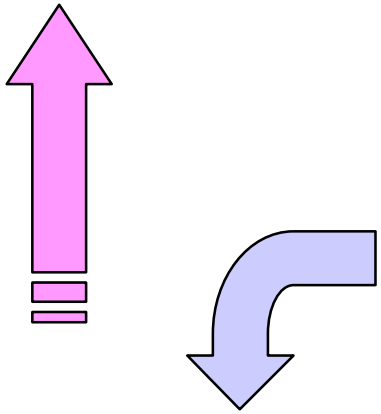


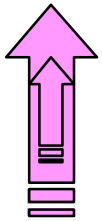
Biological N fixation

Biological N Fixation (BNF) is a photosynthetically derived process where atmospheric N is reduced to ammonium (plant-available form of N) by N-fixing bacteria







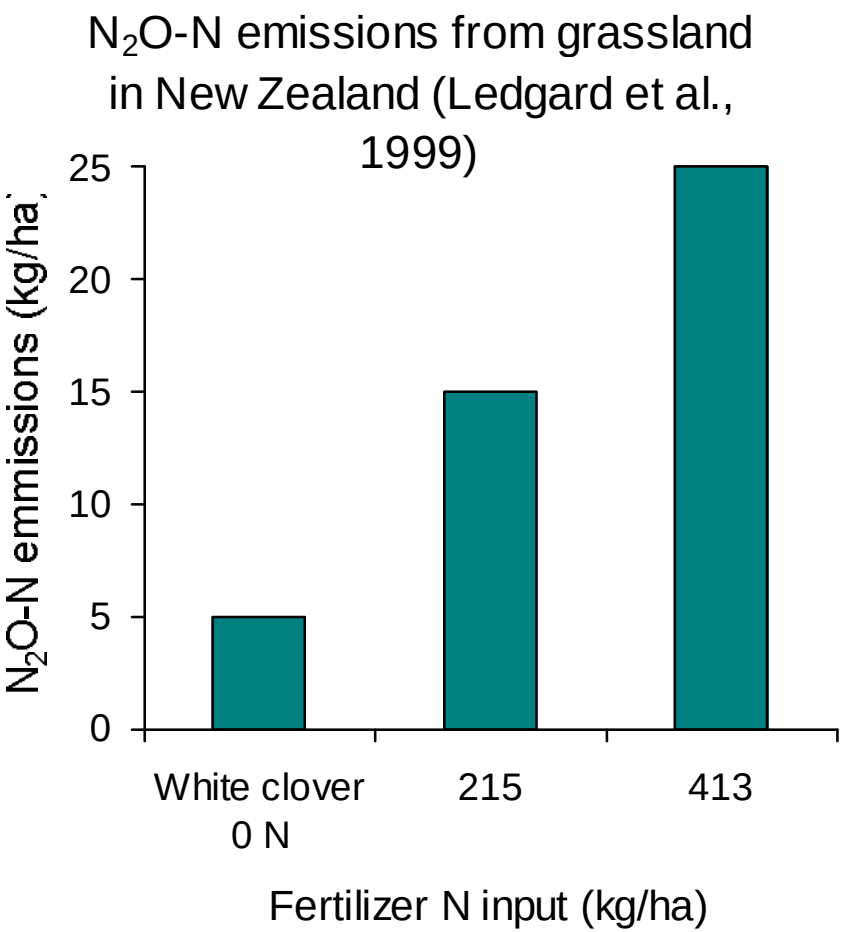


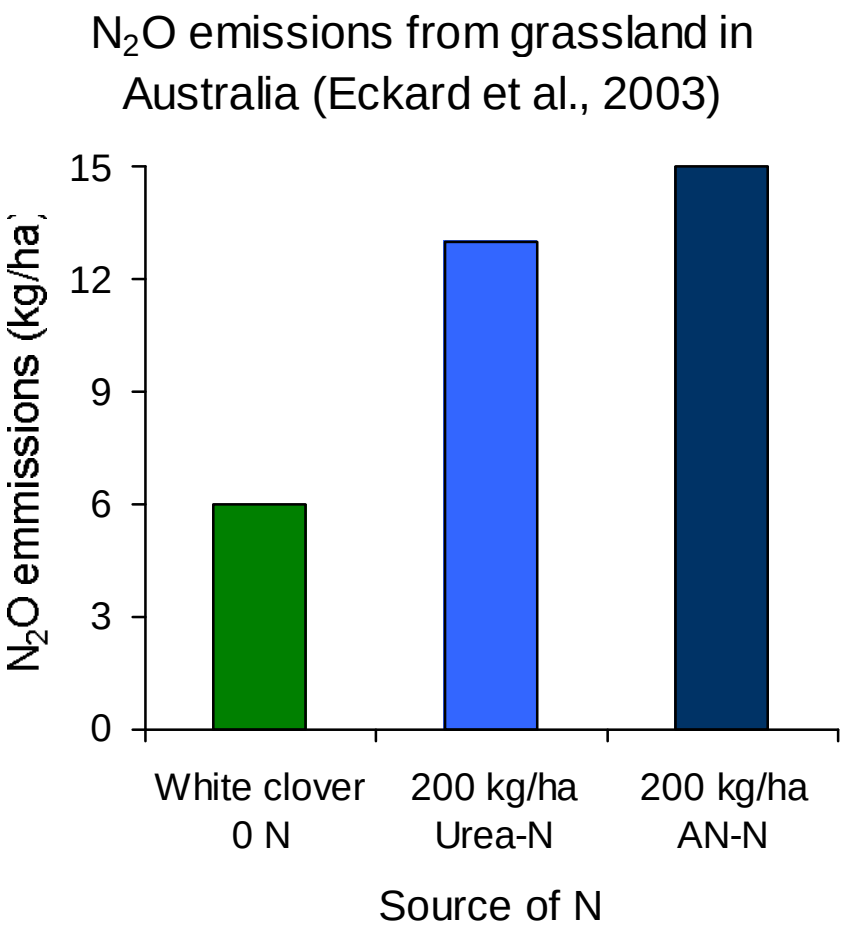
White clover and biologically fixed N (BFN)

- Direct N_2O emissions from white clover not included in current IPCC methodology
- Corré and Kasper (2002) BNF emission factor = 0.2% versus 1.3% for fertilizer N
- Conclusion of recent review for IPCC: No direct N_2O emissions should be attributed to BNF (de Klein *et al*., 2006)
- Photosynthetically derived BNF is “greenhouse gas neutral” (Ledgard *et al*., 2009)
- Upstream CO_2 emissions:

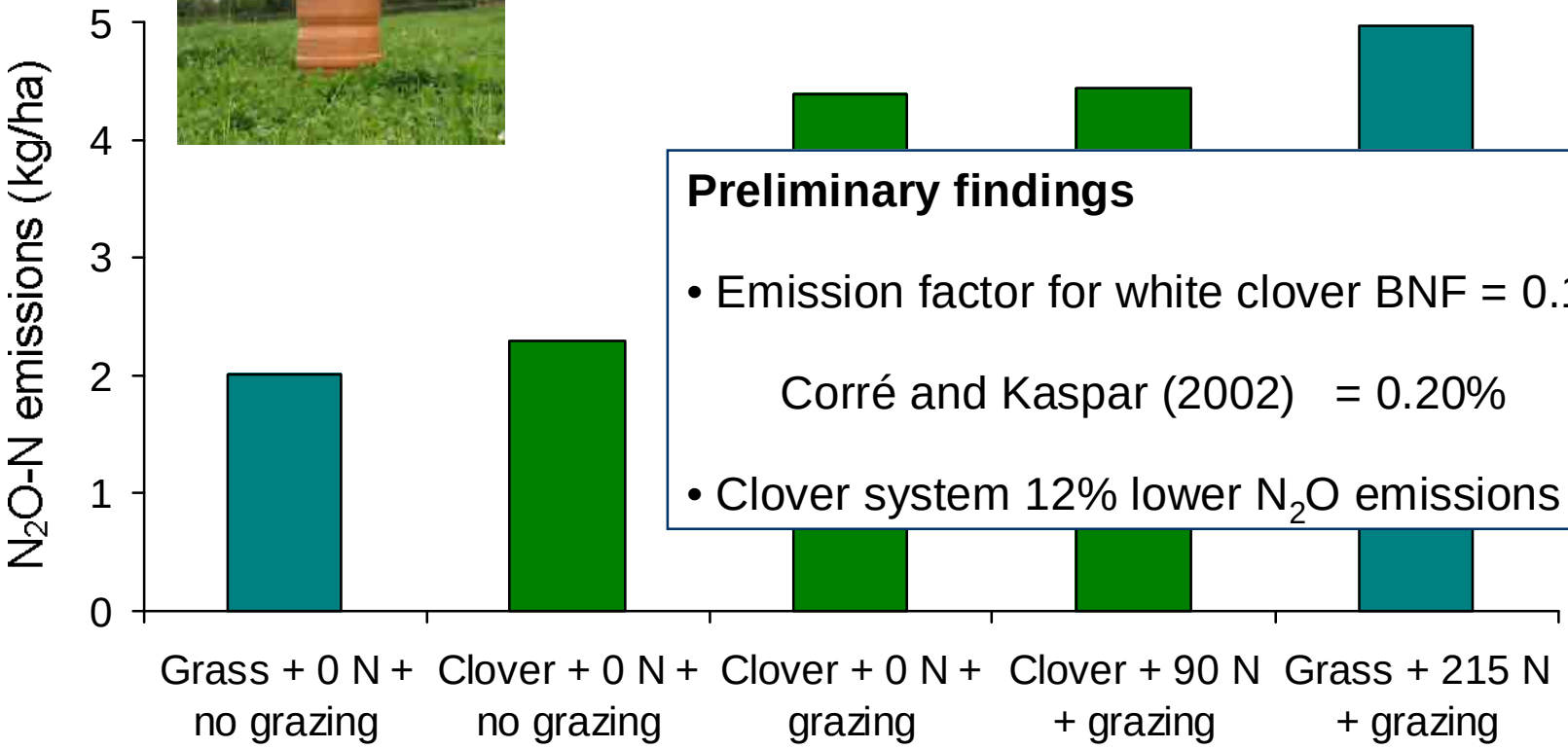
1 t N needs 10 barrels of oil

  - fertilizer N manufacture requires 60 MJ/kg N (Jenssen and Konhshaug, 2003)
  - manufacture, transport and spreading = 3.5 to 4.0 kg CO_2 eq. per kg Urea-N (Williams *et al*., 2006)
- Need LCA to fully determine differences between systems


N_2O-N emissions from grassland in New Zealand (Ledgard et al., 1999)
N_2O-N emmissions (kg/ha)
25
20
15
10
5
0
White clover 0 N
215
413
Fertilizer N input (kg/ha)


N_2O emissions from grassland in Australia (Eckard et al., 2003)
N_2O emmissions (kg/ha)
15
12
9
6
3
0
White clover 0 N
200 kg/ha Urea-N
200 kg/ha AN-N
Source of N

N_2O emissions from clover-based and N-fertilized grassland at Solohead (Li et al., unpublished, RSF 07 516)



Preliminary findings

- Emission factor for white clover BNF = 0.19%

  Corré and Kaspar (2002) = 0.20%

- Clover system 12% lower N_2O emissions

NDP National Development Plan 2007 - 2013

Department of Agriculture, Fisheries and Food
An Roinn Talmhaíochta, Iascaigh agus Bia

SSTI Strategy for Science, Technology and Innovation

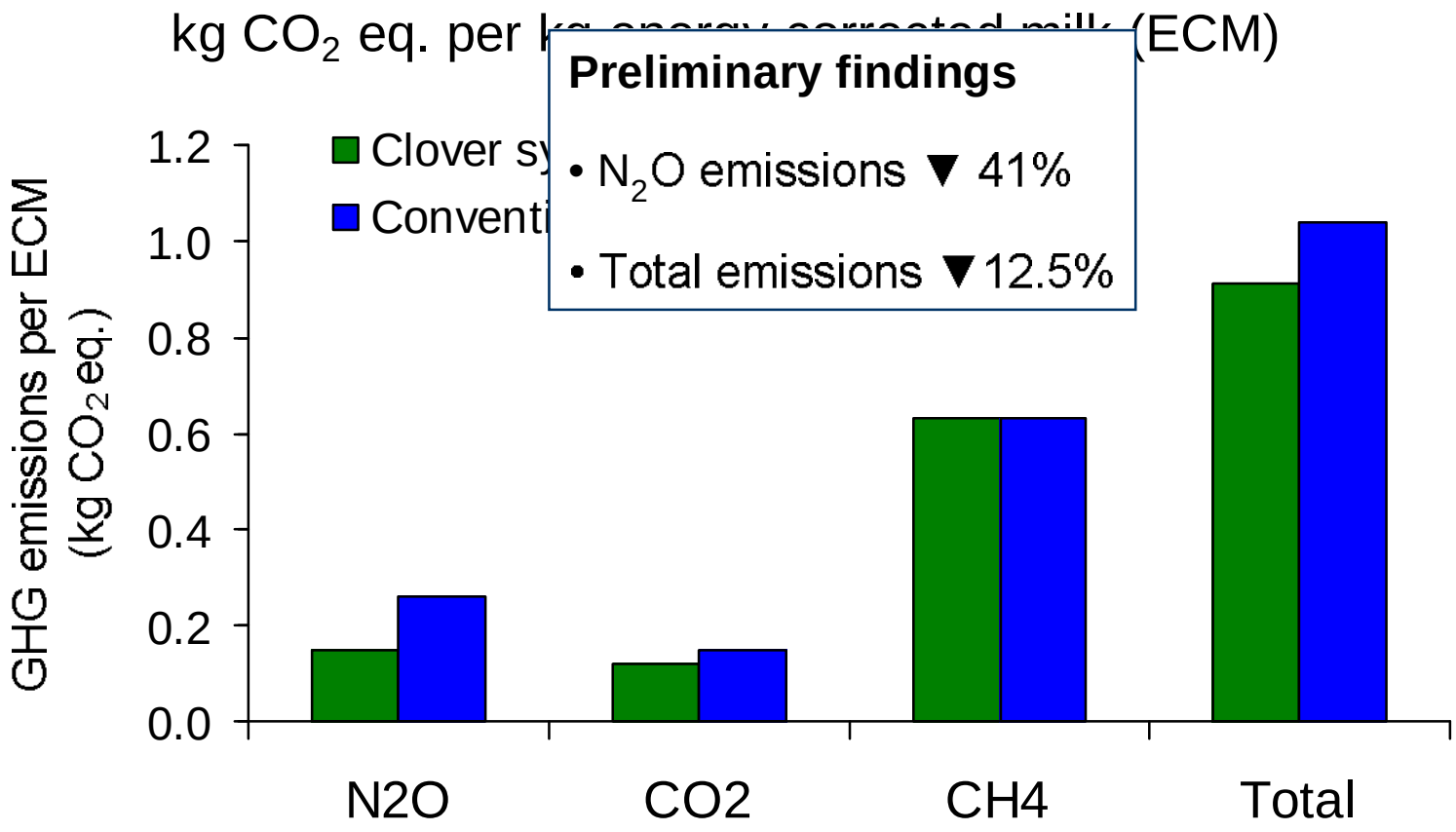
Life Cycle Assessment (LCA) methodology

Primary resources
Raw materials
Energy use
Transport

Inputs
Fertilizers
Electricity
Fuel
Feeds

GHG emissions from Irish clover versus fertilizer N dairy systems

(Humphreys et al. 2009; estimated using LCA methodology; Yan et al. RSF07 516)



NDP National Development Plan 2007 - 2013

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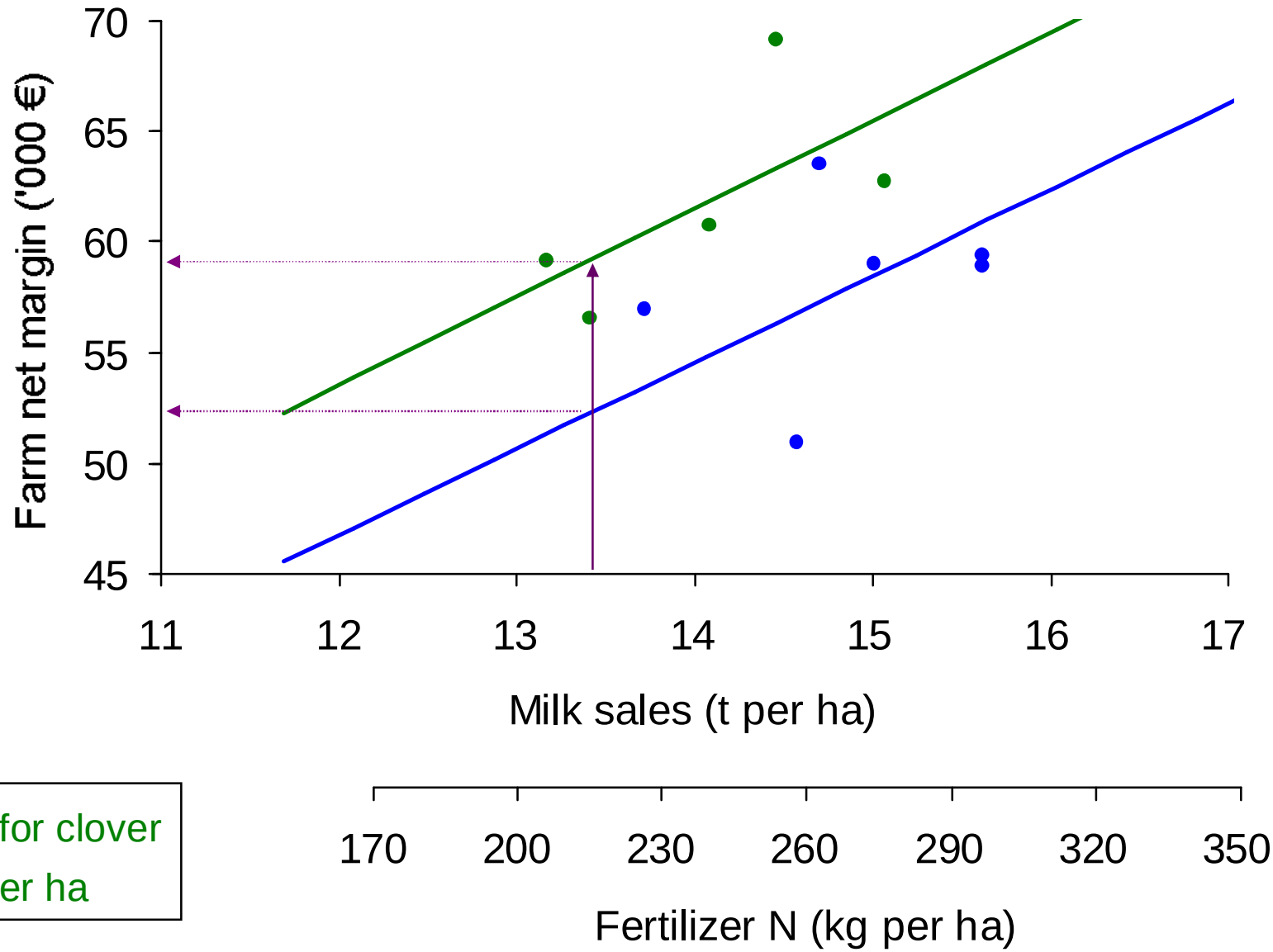
SSTI Strategy for Science, Technology and Innovation

Profitability of clover and fertilizer N-based dairy production

(*Data from* Humphreys *et al*., 2008; 2009; Mihailescu et al. Interreg IVB Dairyman)



Fertilizer N for clover
90 kg per ha

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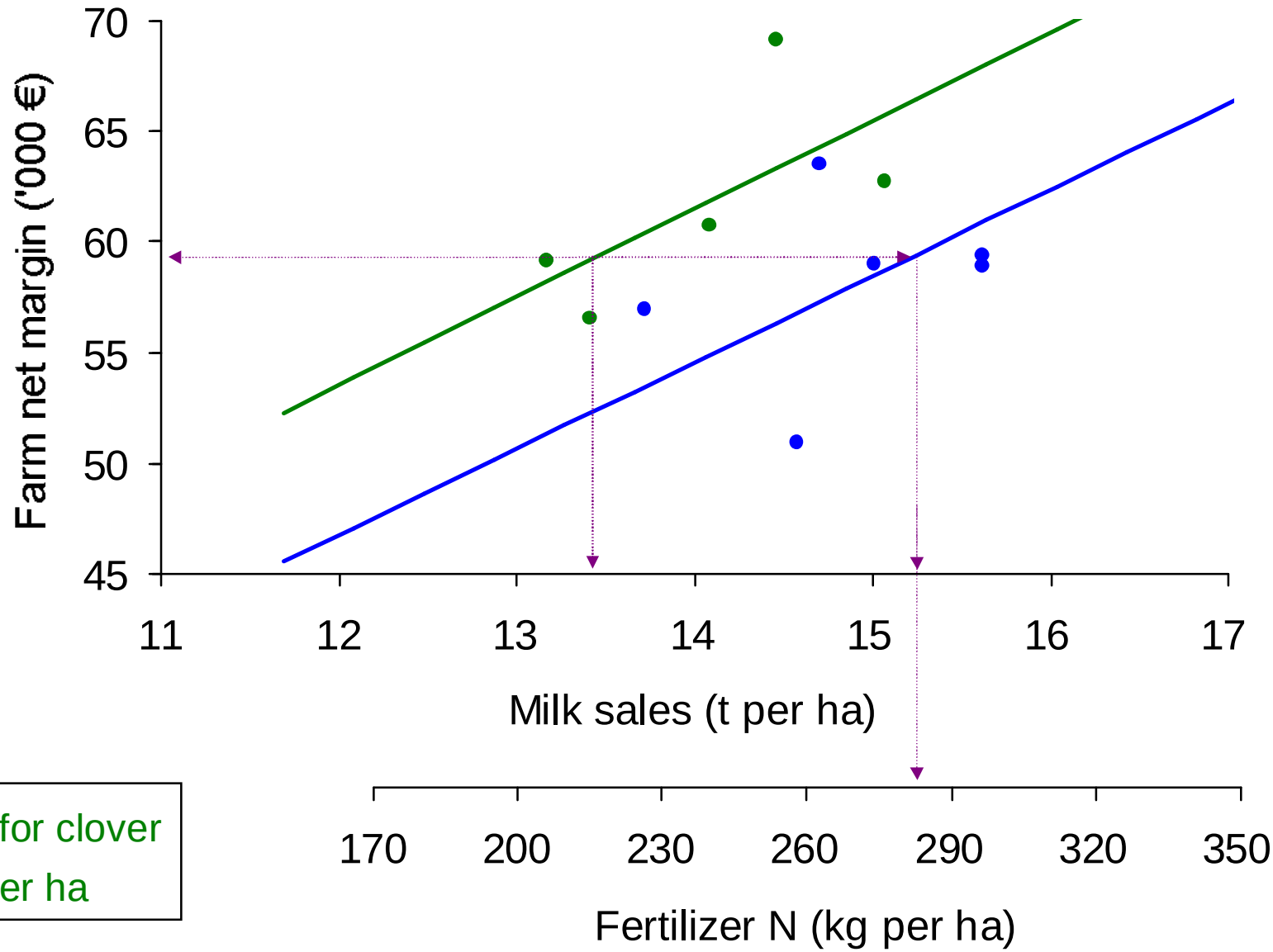
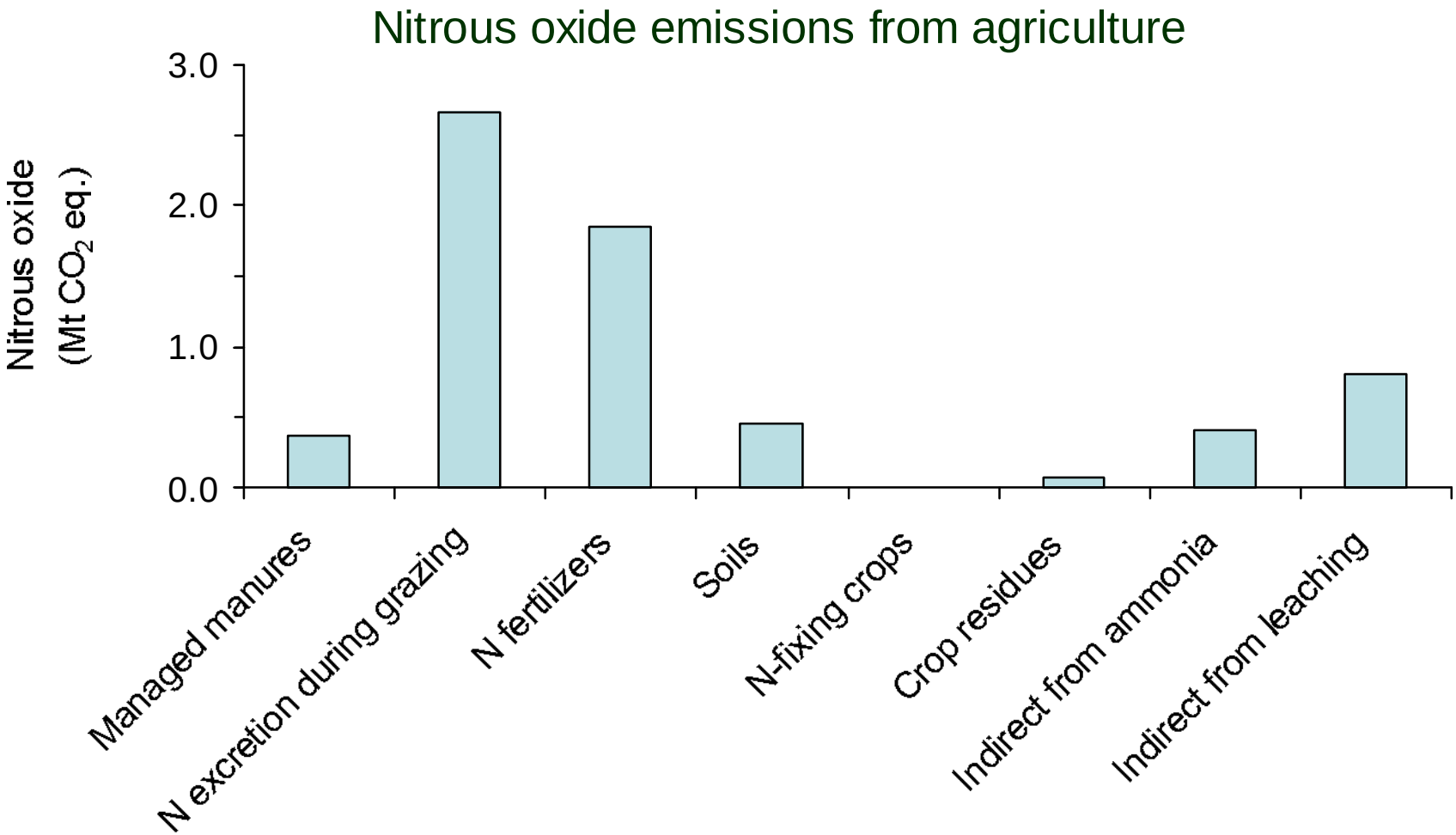


Fertilizer N for clover
90 kg per ha

Implications

- Same net margin with ▼ 0.3 LU per ha and with ▼fertilizer N
- ▼LU = ▼ methane and ▼nitrous oxide (N excretion during grazing)
- ▼ fertilizer N = ▼direct and indirect N_2O emissions



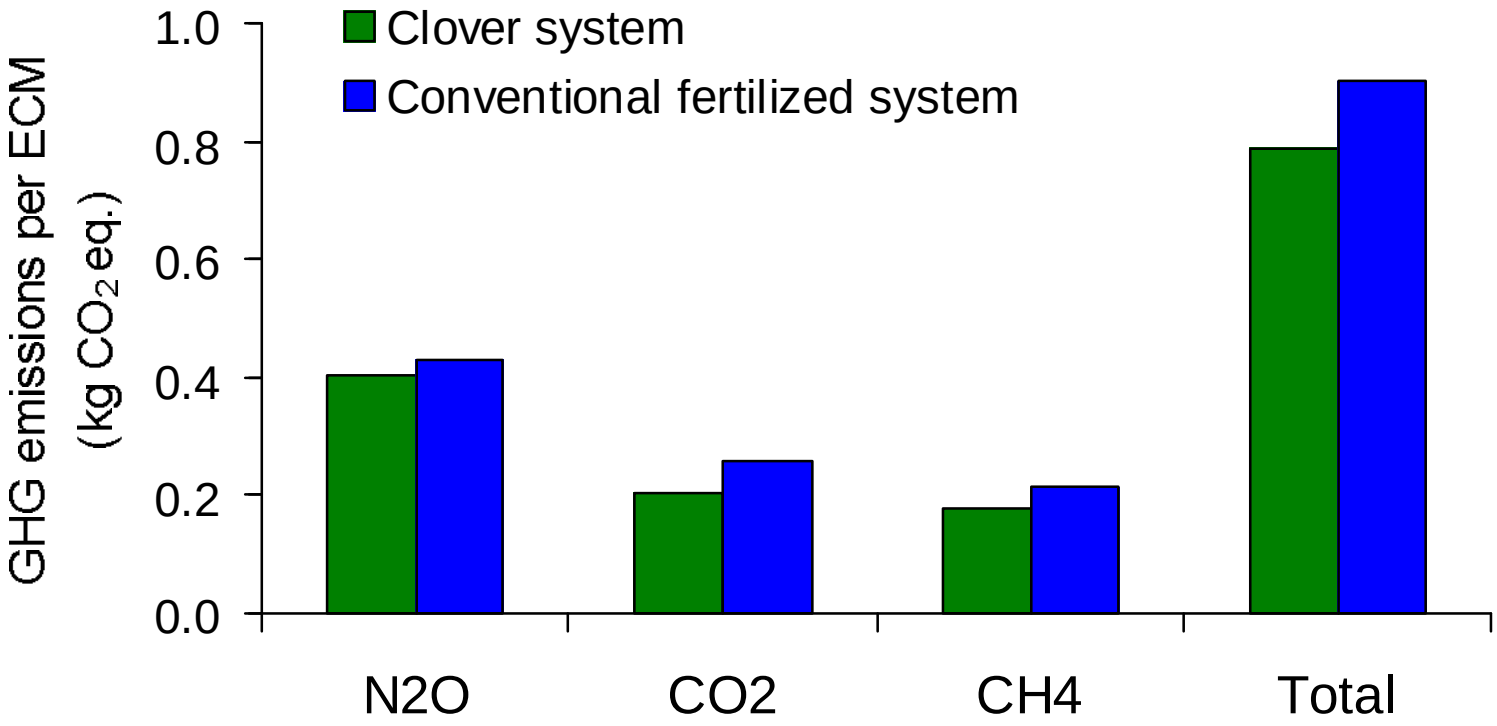
GHG emissions from Dutch clover versus fertilizer N dairy systems

(Schils et al., 2000; Schils et al., 2005)

Two systems: 34.4ha and 40.6 ha; 59 cows per system + followers

kg CO_2 eq. per kg energy corrected milk (ECM)

per kg milk = ▼12.5%



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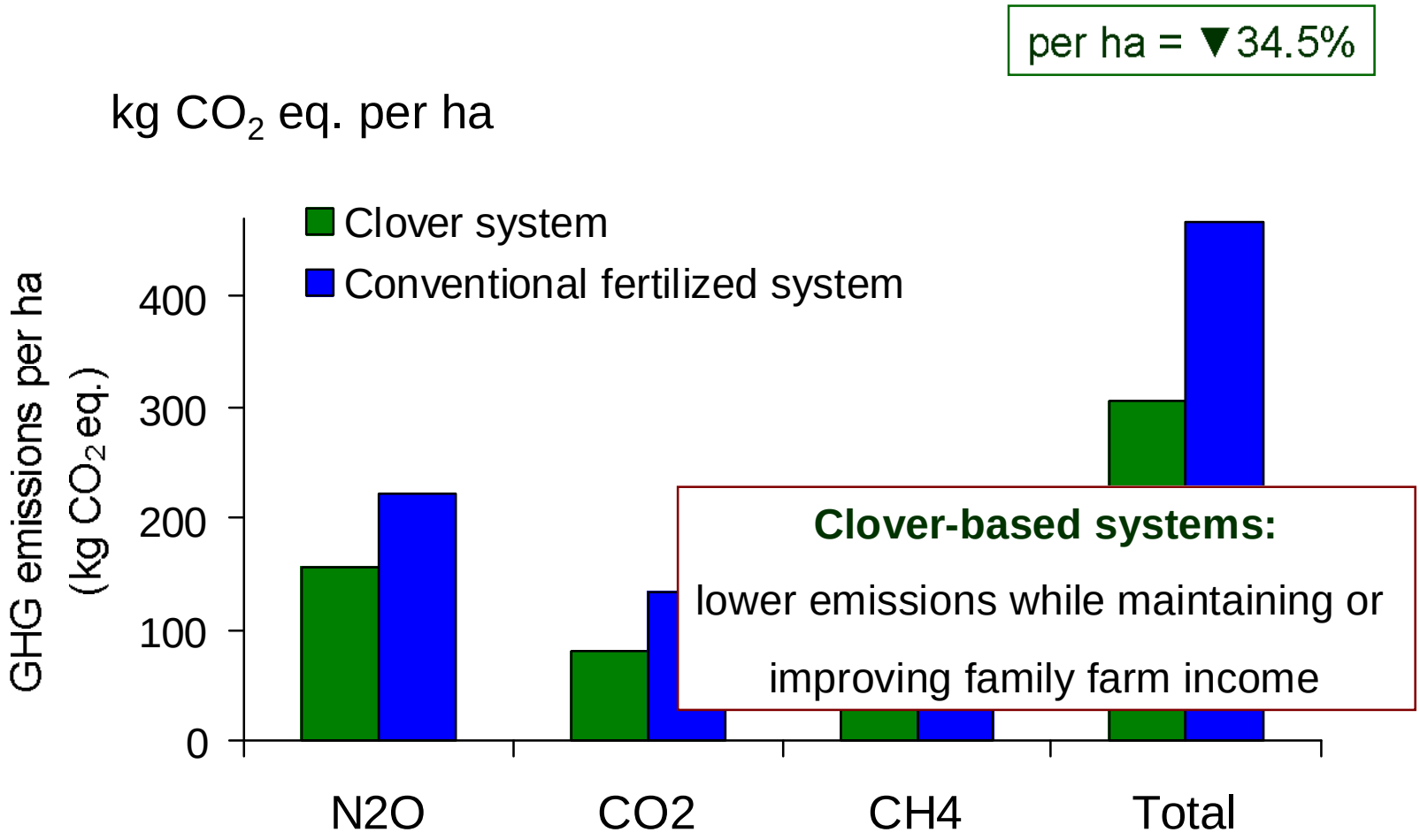
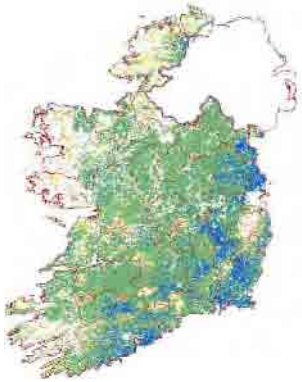


Clover-based systems:

lower emissions while maintaining or improving family farm income

Summary and Conclusions

- Lower N_2O emissions due to less livestock and more efficient N use
- Pressure to increase N use efficiency on farms
- Benefits from current best management practices
- Little incentive to use nitrification inhibitors
- Trailing shoe offer no specific advantages for N_2O emissions
- Clover-based systems offer substantial potential to lower N_2O emissions






“How do we increase food production while reducing emissions”

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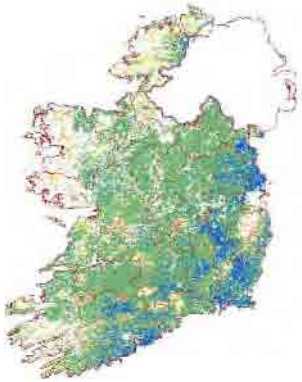




“How do we increase food production while reducing emissions”

- Potential for further cuts in emissions
- Rising cost of energy and fertilizer
- Projecting forward fertilizer N use = 4.5% ▼ in emissions from agriculture

  ≈ 1% ▼in national emissions

- Important to get the message out to farmers (Teagasc)
- Schemes – REPS-4 and AEOS
- Funding, expertise and recruitment embargos