Nitrogen: from the Atmosphere to the Dairy and Back Again

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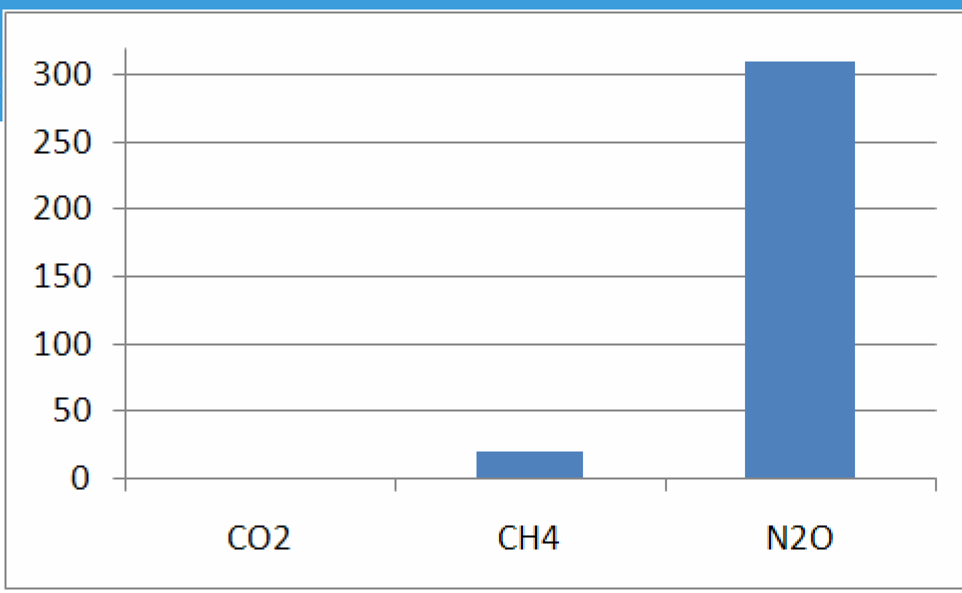
What we breathe:

- 78% nitrogen (N_2)
- 21% oxygen (O_2)
- 1% argon (Ar)
- ~% water vapor (H_2O)
- 380+ ppm carbon dioxide (CO_2) – naturally 200-300
- 18 ppm neon (Ne)
- 1.8 ppm methane (CH_4) – natural was 0.7
- 1 ppm krypton (Kr)
- 0.5 ppm hydrogen (H_2)
- 0.32 ppm nitrous oxide (N_2O) – natural was 0.27

MAIN GREENHOUSE GASES

Greenhouse Gas	Chemical Formula	Pre-Industrial Concentration	Concentration in 2005	Atmospheric Life (years)	Anthropogenic Sources	Global Warming Potential (GWP)
Carbon-dioxide	$C0_2$	280 ppm	379 ppm	Variable	Fossil Fuel Combustion Land Use Conversion Cement Production	1
Methane	CH_4	700 ppb	1774 ppb	12	Fossil Fuel Rice Paddies Landfill Waste Livestock	21
Nitrous oxide	N_20	275 ppb	319 ppb	114	Fertilisers Combustion Industrial Processes	310



Greenhouse Warming Potential

Locally elevated gasses:

- Ozone – 75 ppb is 8 hour Federal standard
- NO_x (NO and NO_2) – 53 ppb annual US
  - Brown, leads to secondary (fine) aerosol and ozone
- NH_3
  - Odor, leads to secondary (fine) aerosol
- VOCs (hundreds of compounds in ppb range)
  - Leads to ozone and secondary (fine) aerosol
- CFCs

Aside from N-containing VOCs:

- N_2
- NH_3
- NO and NO_2 (interchanged by sun/ozone)
- N_2O – the #3 greenhouse gas

- Plus the aqueous ion 'siblings':
  - NH_4+ and NO_3-/NO_2-

‘fixation’ $N_2 \rightarrow NH_3$

‘denitrification’ NO_3- $\rightarrow N_2$

($NH_3 \rightarrow NO_3$- is oxidation)

These are natural processes,
but elevated by human activity,
especially since the industrial revolution

The Haber process now produces 100 million tons of nitrogen fertilizer per year, mostly as anhydrous ammonia, ammonium nitrate and urea.

Estimated to consume ~1-2% of humans' annual energy use

Simple N-molecules in the air, with oxidation state of N in [brackets]

N_2[0]

NH_3[-3] N_2O[+1] NO[+2] NO_2[+4] HNO_3[+5]

^^^^^^^^^

NO_x=NO+NO_2

(others include nitro-compounds, nitrates, PANs, etc..)

Simple N-molecules in the soil and groundwater

(also a wide variety of organoN compounds)

NH_3 and NH_4+

N_2

N_2O

NO

NO_3- and NO_2-

Ecological Applications 1997 Human Alteration of Global Nitrogen Cycle

HUMAN ALTERATION OF THE GLOBAL NITROGEN CYCLE: SOURCES AND CONSEQUENCES

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Abstract. Nitrogen is a key element controlling the species composition, diversity, dynamics, and functioning of many terrestrial, freshwater, and marine ecosystems. Many of the original plant species living in these ecosystems are adapted to, and function optimally in, soils and solutions with low levels of available nitrogen. The growth and dynamics of herbivore populations, and ultimately those of their predators, also are affected by N. Agriculture, combustion of fossil fuels, and other human activities have altered the global cycle of N substantially, generally increasing both the availability and the mobility of N over large regions of Earth. The mobility of N means that while most deliberate applications of N occur locally, their influence spreads regionally and even globally. Moreover, many of the mobile forms of N themselves have environmental consequences. Although most nitrogen inputs serve human needs such as agricultural production, their environmental consequences are serious and long term.

Based on our review of available scientific evidence, we are certain that human alterations of the nitrogen cycle have:

1) approximately doubled the rate of nitrogen input into the terrestrial nitrogen cycle, with these rates still increasing;

2) increased concentrations of the potent greenhouse gas N_2O globally, and increased concentrations of other oxides of nitrogen that drive the formation of photochemical smog over large regions of Earth;

3) caused losses of soil nutrients, such as calcium and potassium, that are essential for the long-term maintenance of soil fertility;

4) contributed substantially to the acidification of soils, streams, and lakes in several regions; and

5) greatly increased the transfer of nitrogen through rivers to estuaries and coastal oceans.

In addition, based on our review of available scientific evidence we are confident that human alterations of the nitrogen cycle have:

6) increased the quantity of organic carbon stored within terrestrial ecosystems;

7) accelerated losses of biological diversity, especially losses of plants adapted to efficient use of nitrogen, and losses of the animals and microorganisms that depend on them; and

8) caused changes in the composition and functioning of estuarine and nearshore ecosystems, and contributed to long-term declines in coastal marine fisheries.

Ecological
Applications
1997

- Doubled the rate of N flow
- Increased N_2O
- Greatly increased N to waters
- Contributed to acidification (HNO_3)
- Caused loss of K, Ca, other nutrients
- Increased quantity of organic carbon stored within terrestrial ecosystems

Ecological Applications 1997

Anthropogenic Percentage of Total Emissions

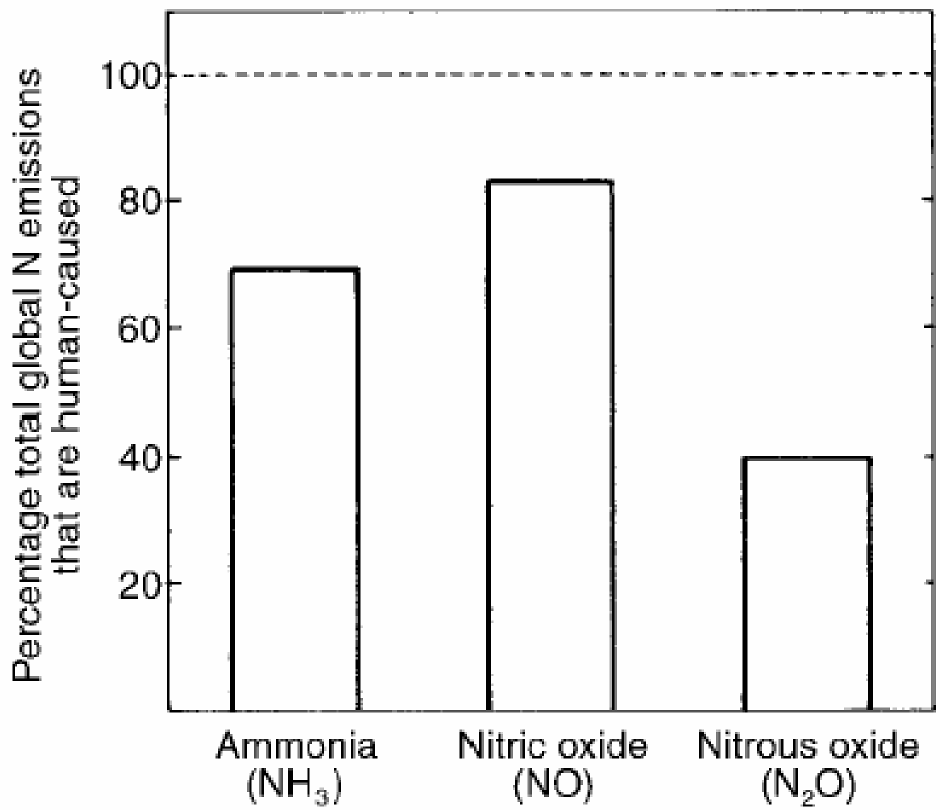

FIG. 3. The anthropogenic contribution to the total emissions of nitrogen-containing trace gases. Ammonia data are from Schlesinger and Hartley (1992), nitric oxide from Delmas et al. (*in press*), and nitrous oxide from Prather et al. (1995).

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MICROBIOLOGICAL REVIEWS, Dec. 1996, p. 609–640 Vol. 60, No
0146-0749/96/$04.00+0

Soil Microorganisms as Controllers of Atmospheric Trace Gases (H_2, CO, CH_4, OCS, N_2O, and NO)

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Soil microbes take up N_2, but also NO, NO_2, N_2O, and others.

Of course, they also emit.

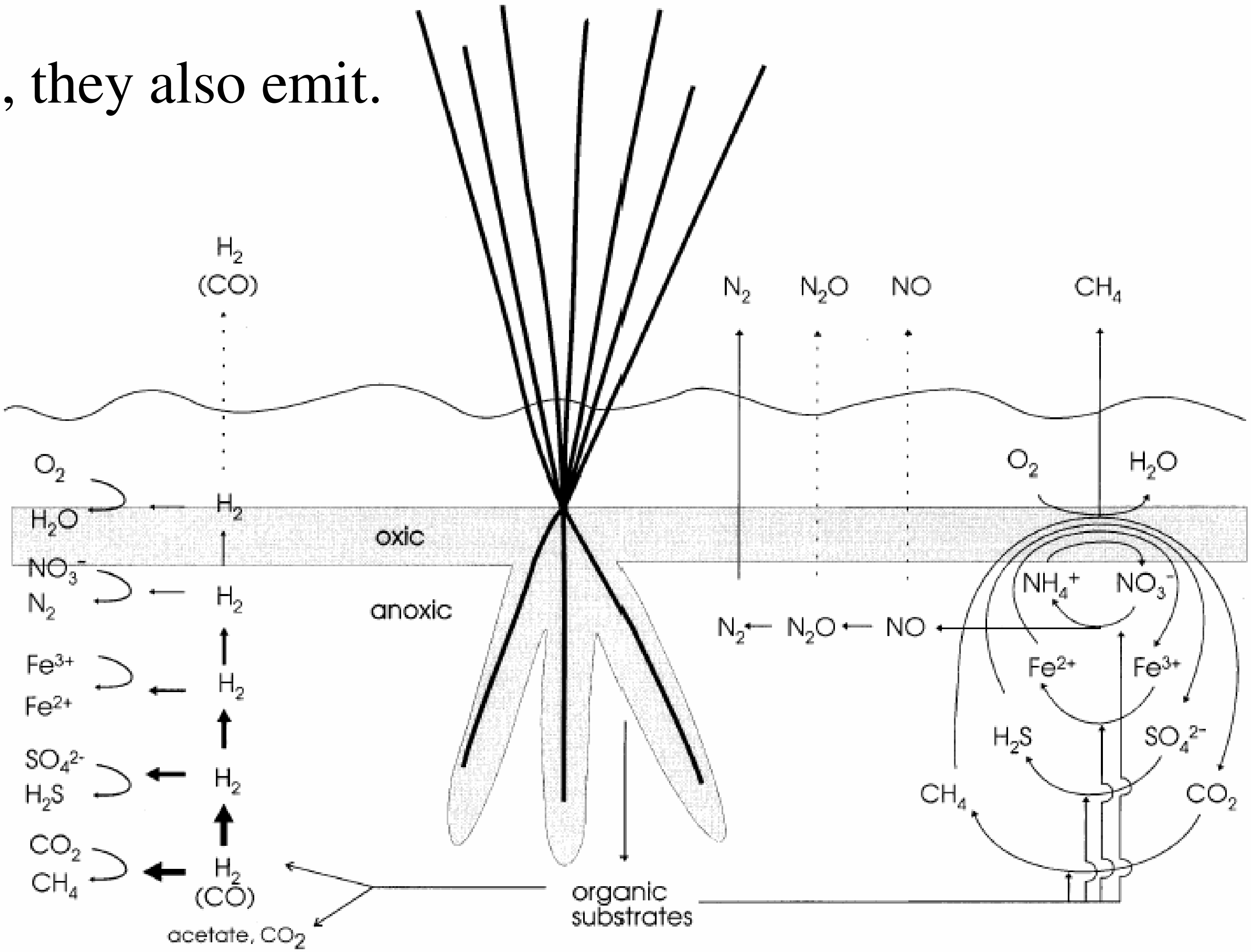

FIG. 3. Conceptual scheme of the vertical distribution of different redox reactions that influence the flux of H_2 and other trace gases (CO, CH_4, NO, and N_2O) from submerged vegetated soil and of the reoxidation of reduced inorganic electron acceptors by O_2 in the oxic layers at the soil-water interface and the rhizosphere of aquatic plants.

Groundwater studies – active area of current research.

Environ. Sci. Technol. **2007**

Saturated Zone Denitrification: Potential for Natural Attenuation of Nitrate Contamination in Shallow Groundwater Under Dairy Operations

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We present results from field studies at two central California dairies that demonstrate the prevalence of saturated-zone denitrification in shallow groundwater with $^3H/^3He$ apparent ages of <35 years. Concentrated animal feeding operations are suspected to be major contributors of nitrate to groundwater, but saturated zone denitrification could mitigate their impact to groundwater quality.

Available online at www.sciencedirect.com

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Modelling greenhouse gas emissions from European conventional and organic dairy farms

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Available online 12 October 2005

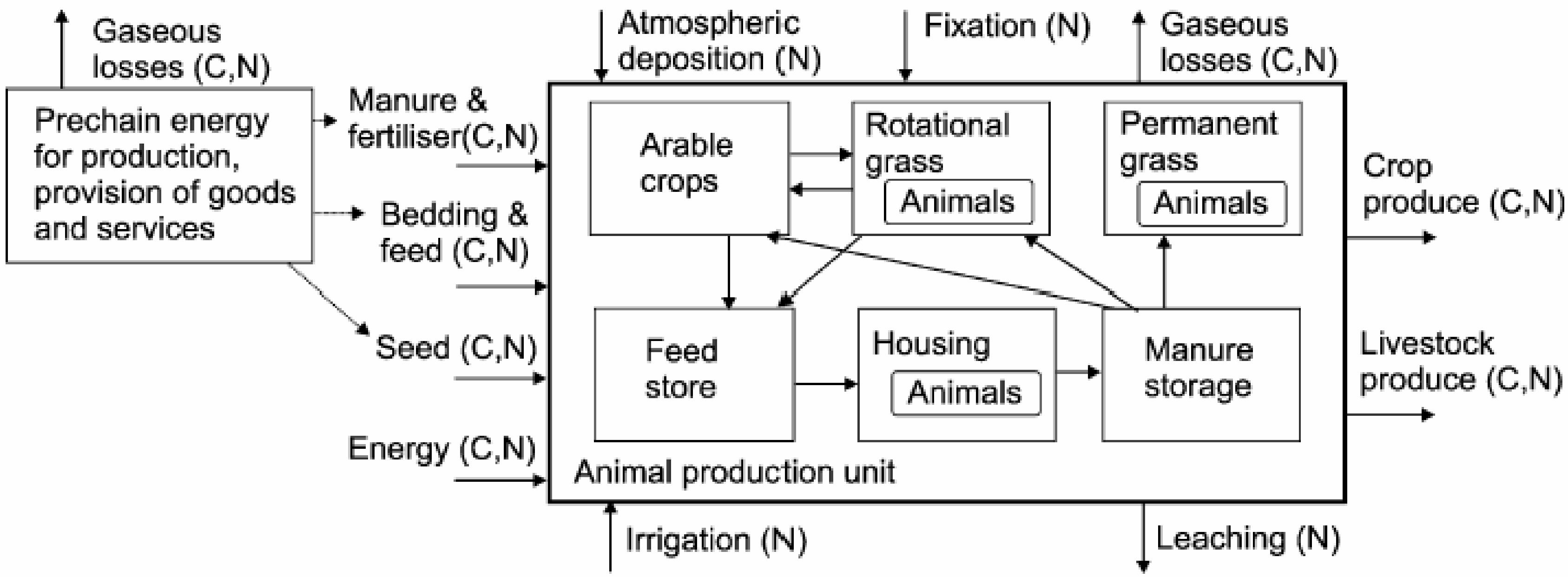
Abstract

Agriculture is an important contributor to global emissions of greenhouse gases (GHG), in particular for methane (CH_4) and nitrous oxide (N_2O). Emissions from farms with a stock of ruminant animals are particularly high due to CH_4 emissions from enteric fermentation and manure handling, and due to the intensive nitrogen (N) cycle on such farms leading to direct and indirect N_2O emissions. The whole-farm model, FarmGHG, was designed to quantify the flows of carbon (C) and nitrogen (N) on dairy farms. The aim of the model was to allow quantification of effects of management practices and mitigation options on GHG emissions. The model provides assessments of emissions from both the production unit and the pre-chains. However, the model does not quantify changes in soil C storage.

Model dairy farms were defined within five European agro-ecological zones for both organic and conventional systems. The model farms

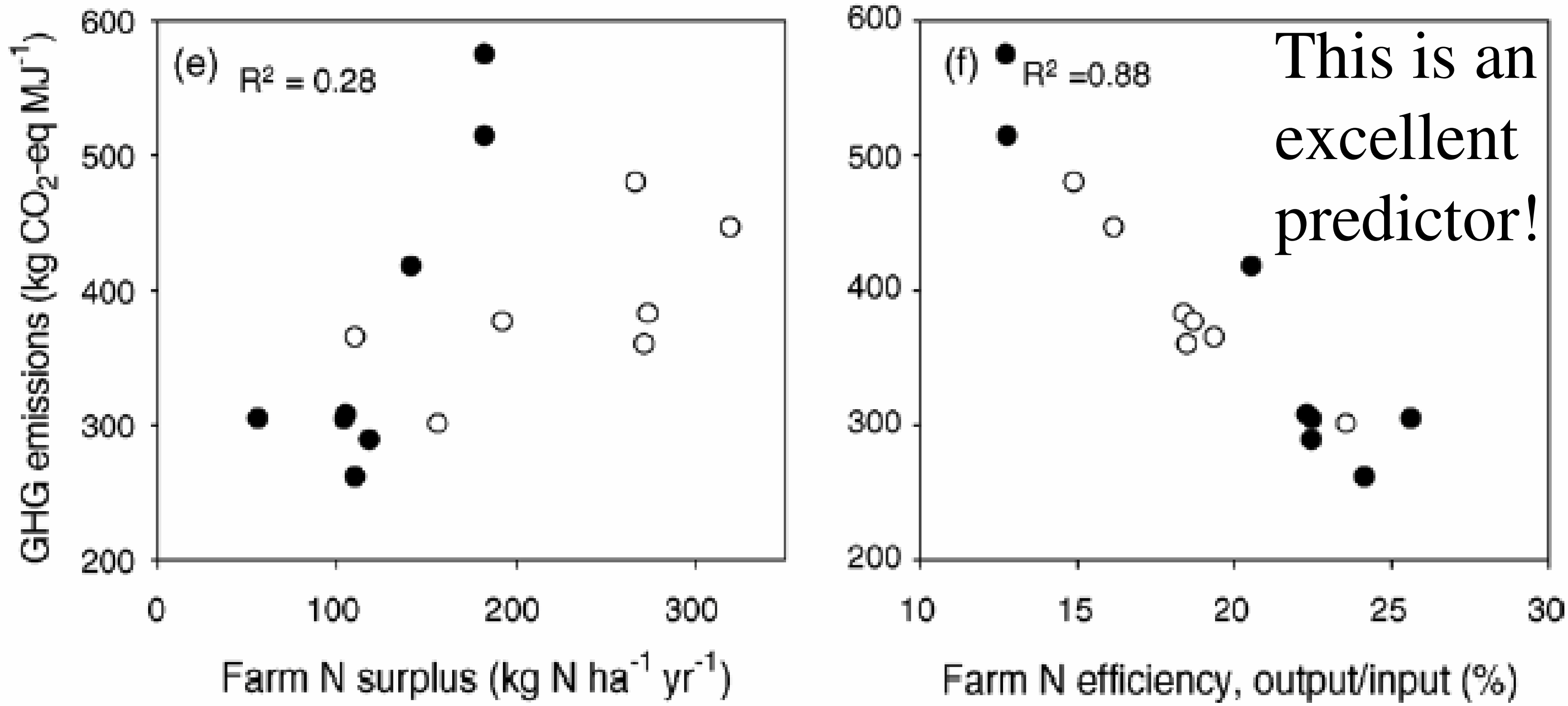
Modelling the complete C, N input-output cycle for GHGs.

(Agriculture, Ecosystems, & Environment 2006 Olesen et al)



Flows of C and N in and out of the total model farm system and between compartments within the system represented in FarmGHG.

Compared GHG emissions relative to land area, milk volume, ….but the best summary is by energy value of product:

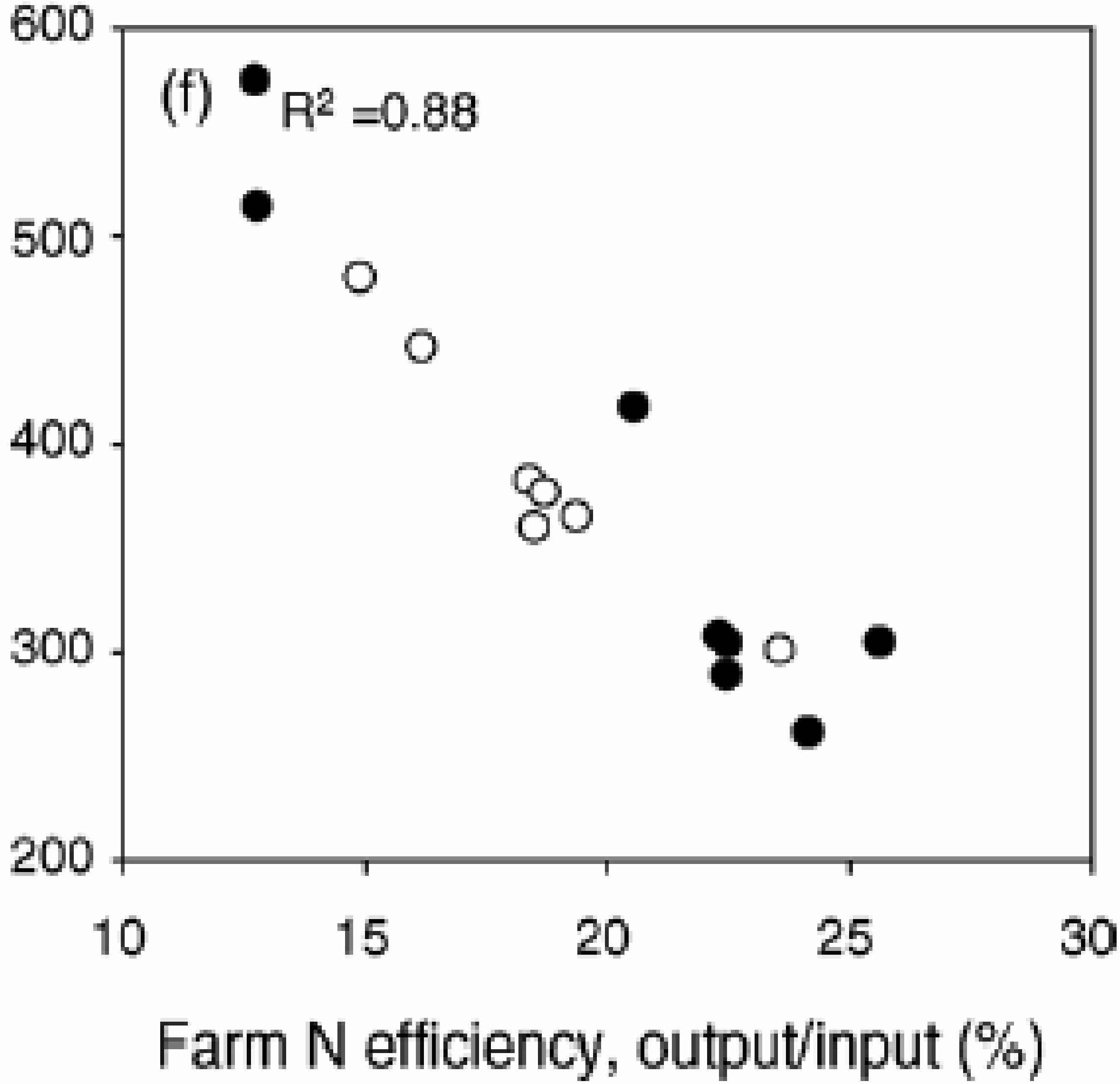


This is an excellent predictor!

ouse gas emissions depending on farm N surplus (a, c and e) and on farm N efficiency (b, d and f). The emissions are sh), emissions per kg milk produced (c and d), and emissions per MJ of metabolic energy in the exported milk, meat an nination of the relationships (R^2) is indicated.

(Agriculture, Ecosystems, & Environment 2006 Olesen et al)

GHG emissions per energy value of product are optimized by increasing Farm N efficiency:

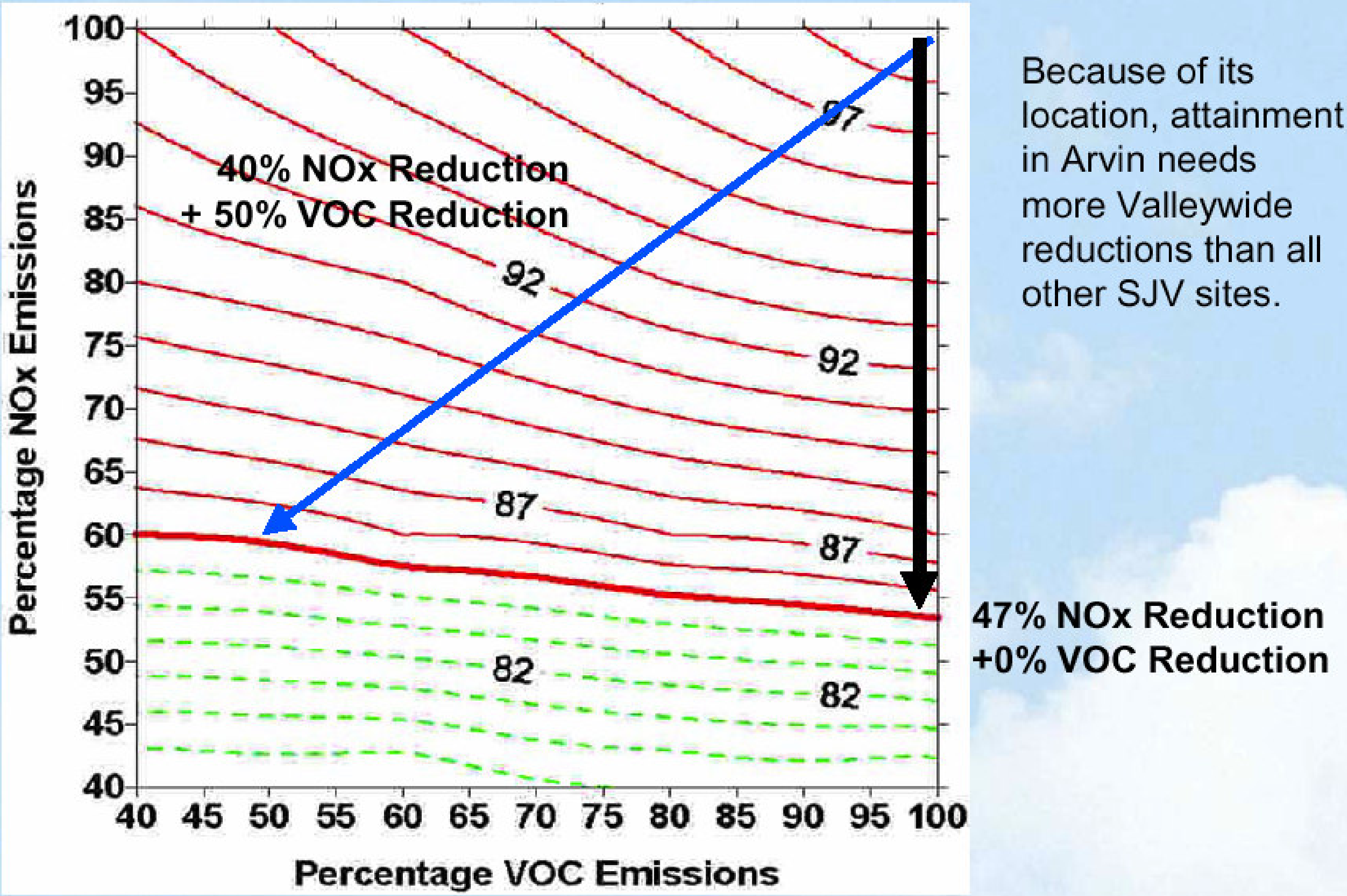


To minimize GHG per unit of product energy…

Maximize N utilization efficiency:

Output/Input >20% is very good.

Ozone Model Response At Arvin Monitor Site to Reductions in 2020 VOC and NOx Emissions



Because of its location, attainment in Arvin needs more Valleywide reductions than all other SJV sites.