Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Reducing Greenhouse Gas Contribution from Ruminant Livestock

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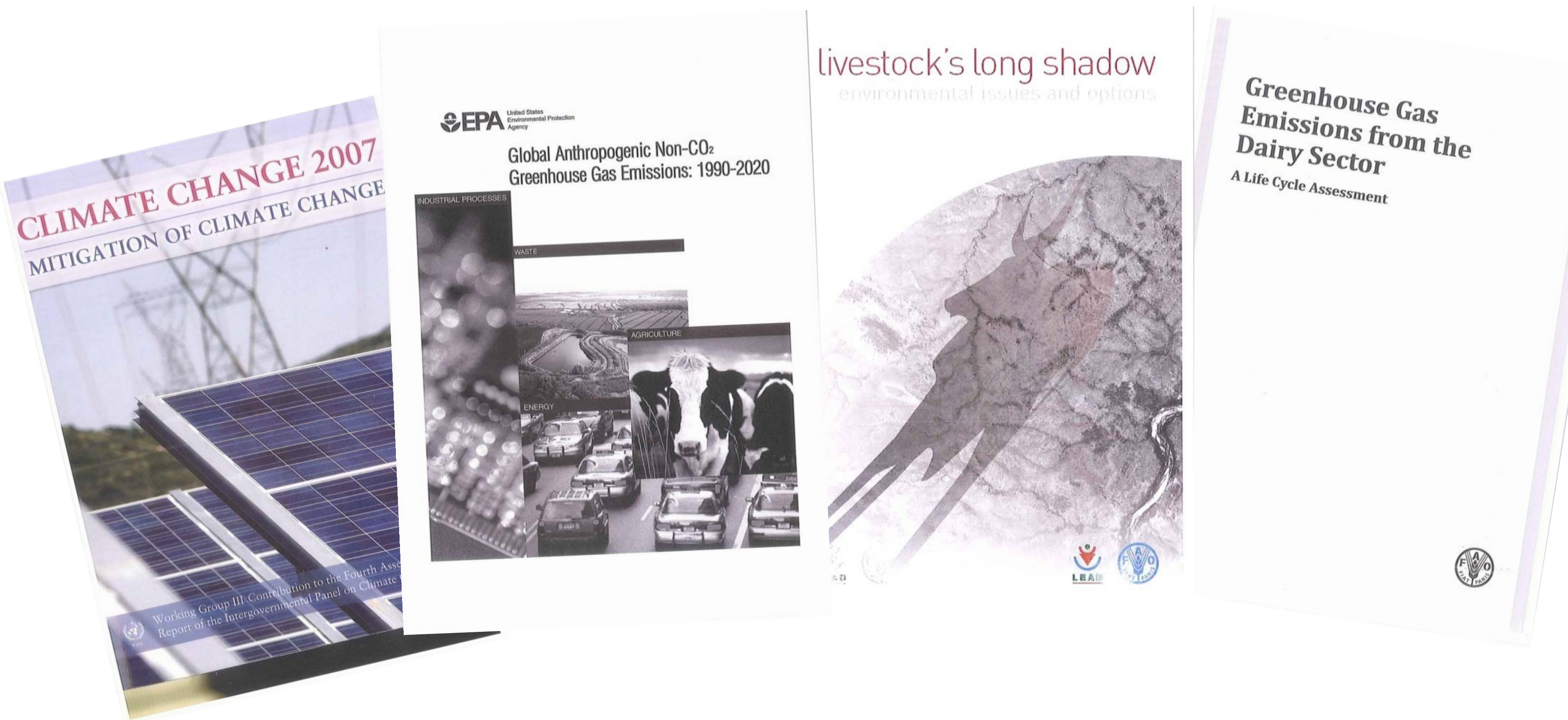
Lethbridge Research Centre, Lethbridge, Alberta, Canada

Canada

Outline

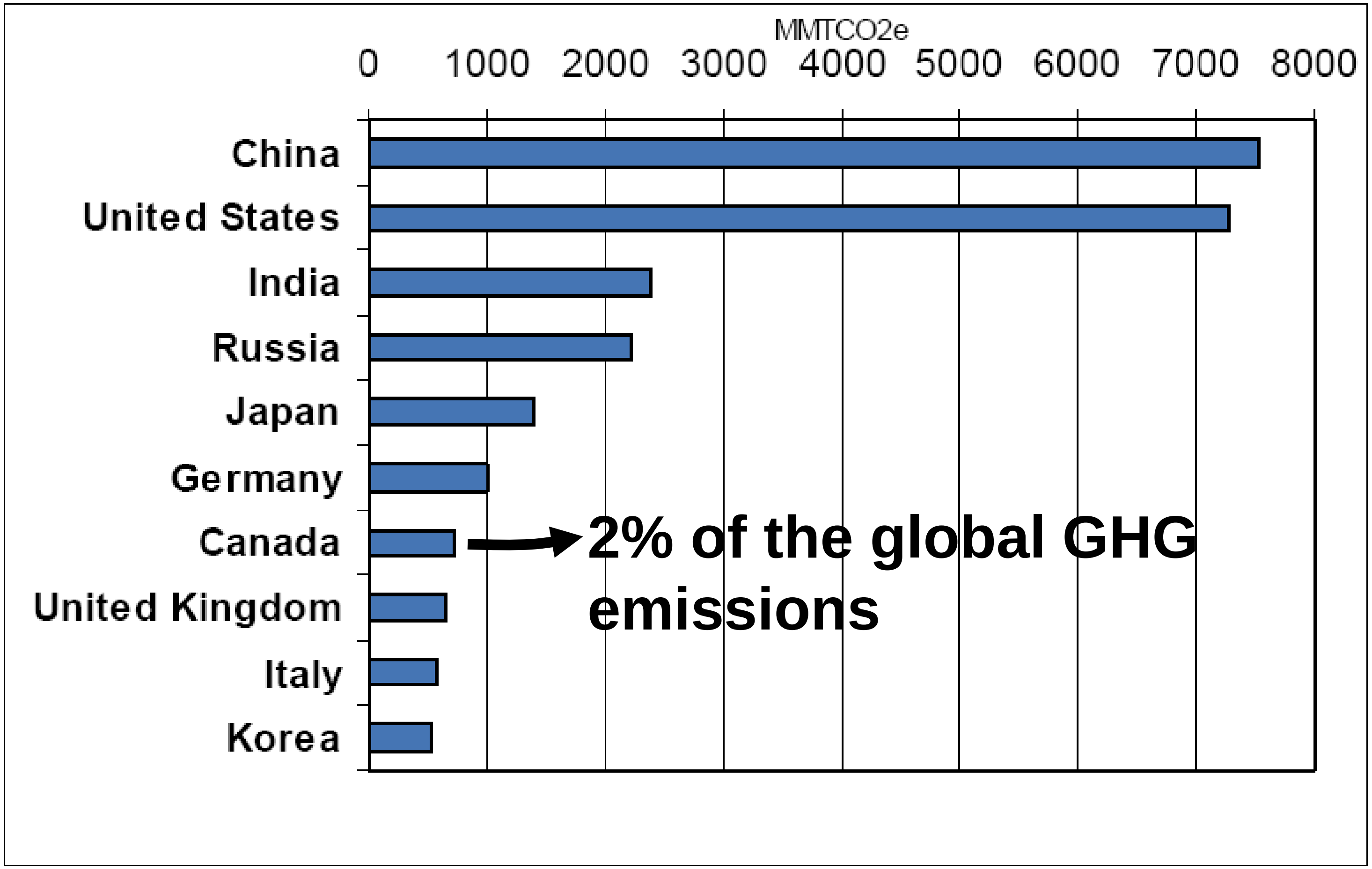
- Contribution of livestock to GHG emissions
- Measuring emissions
- Potential for mitigation
- “Holo”-istic approach – whole farm modeling
- Future perspectives

GHG emmisions - Global issue receiving a lot of attention



Animal scientists need to be aware of this issue

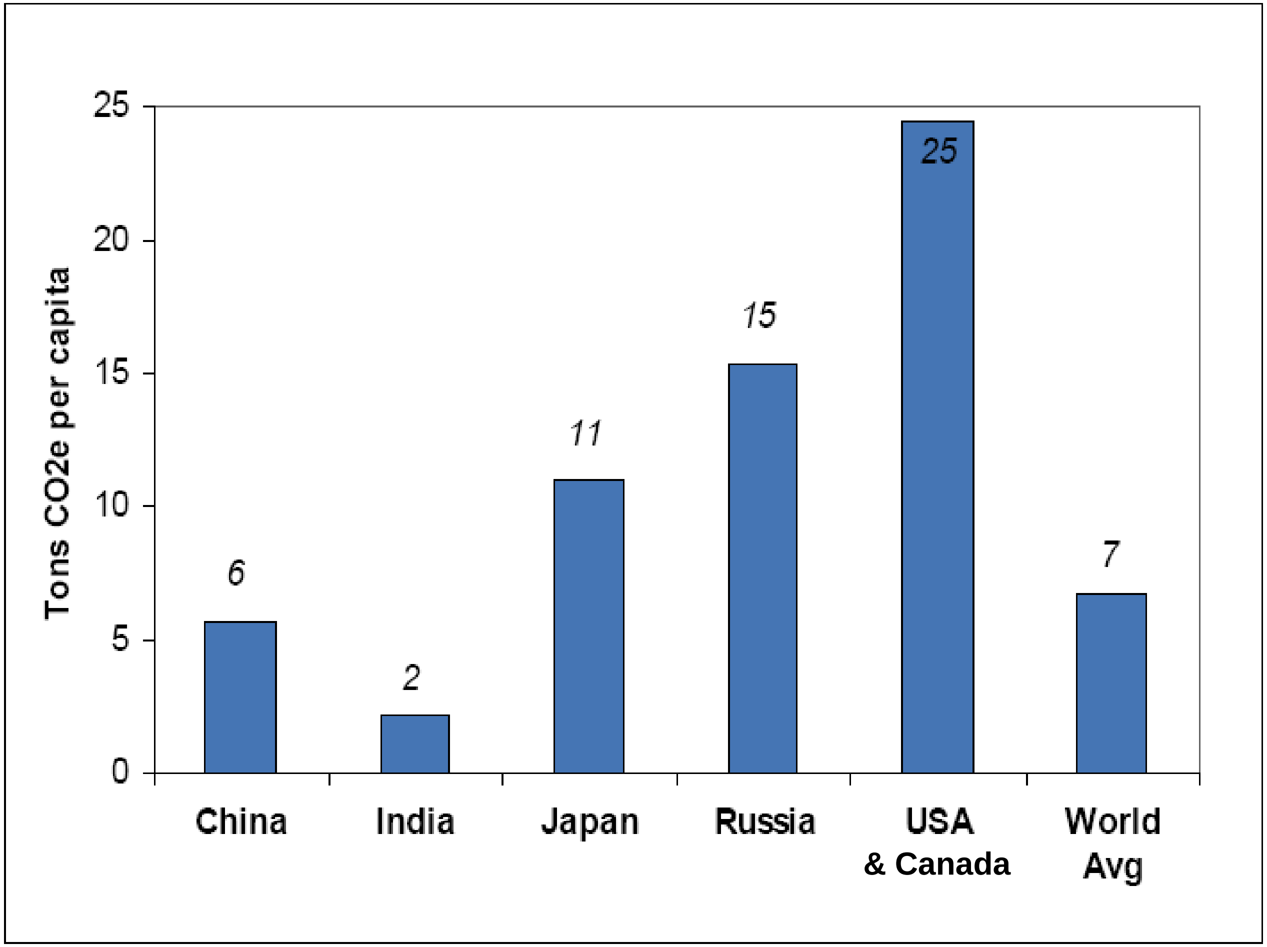
Figure 2. Top GHG Emitters in 2005



Source: CRS graphic from IEA estimates (extracted January 8, 2008).

http://www.fas.org/sgp/crs/row/RL34659.pdf

Figure 3. Estimated Per Capita GHG Emissions in 2005

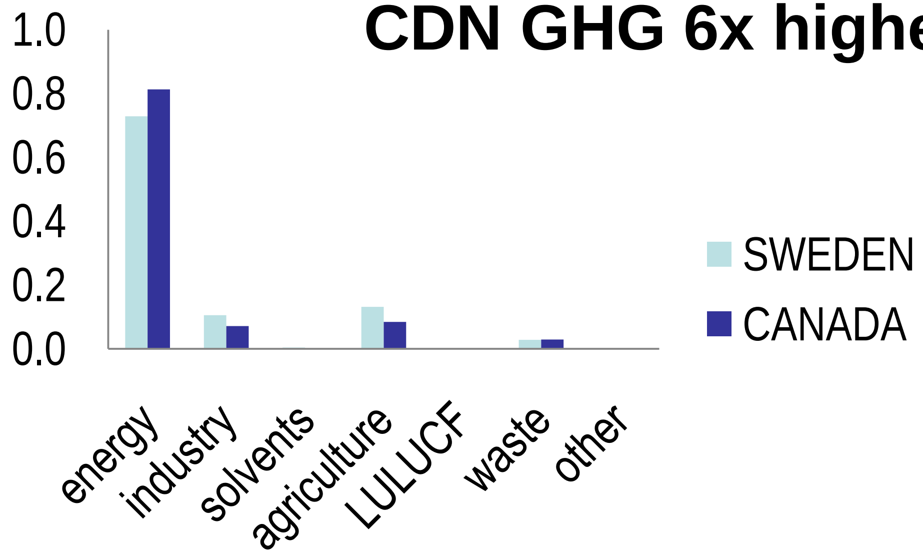


Source: CRS graph from IEA estimates for 2005 (extracted January 8, 2008).

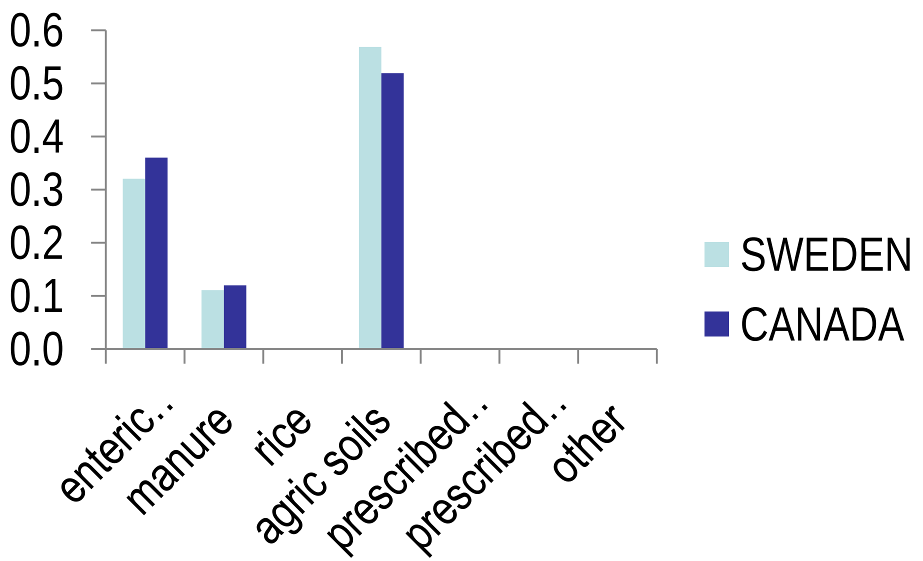
http://www.fas.org/sgp/crs/row/RL34659.pdf

CDN GHG 6x higher than SW

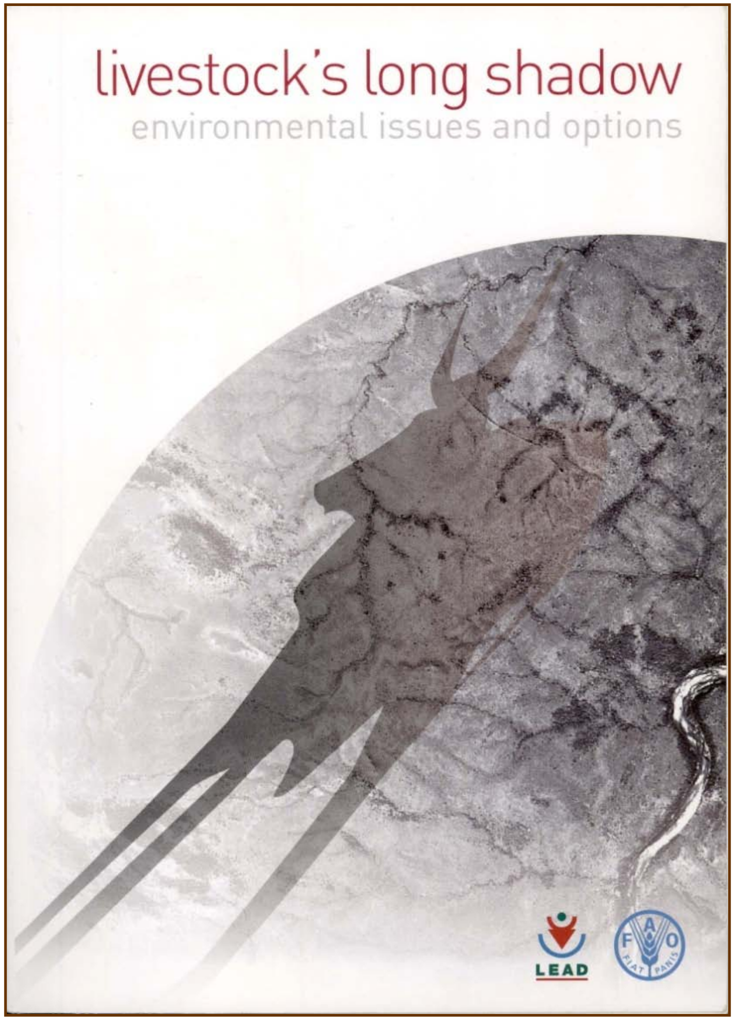
Proportion of total GHG for the country



Proportion of agricultural GHG by source

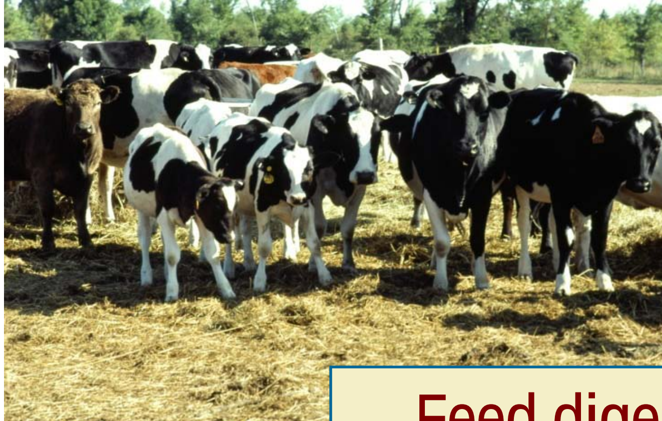


Livestock's Long Shadow Report, FAO 2006



- “Livestock is one of the top three most significant contributors to environmental problems.”
- “Livestock and their manure account for 18% of global GHG emissions”
- “Ruminants worst offenders because of enteric methane.”

Livestock sector is under increasing pressure to be more environmentally sustainable



Feed digestion by ruminants

Animal production contributes to GHG emissions

(8-18% of all GHG emissions)

Manure

Feed production

Land use

Livestock contribution to GHG

- FAO Long Shadow report (2006)
  - 18% of global emissions
  - Included production of feed to animals, production of inputs, transport and processing, deforestation, changes in land use

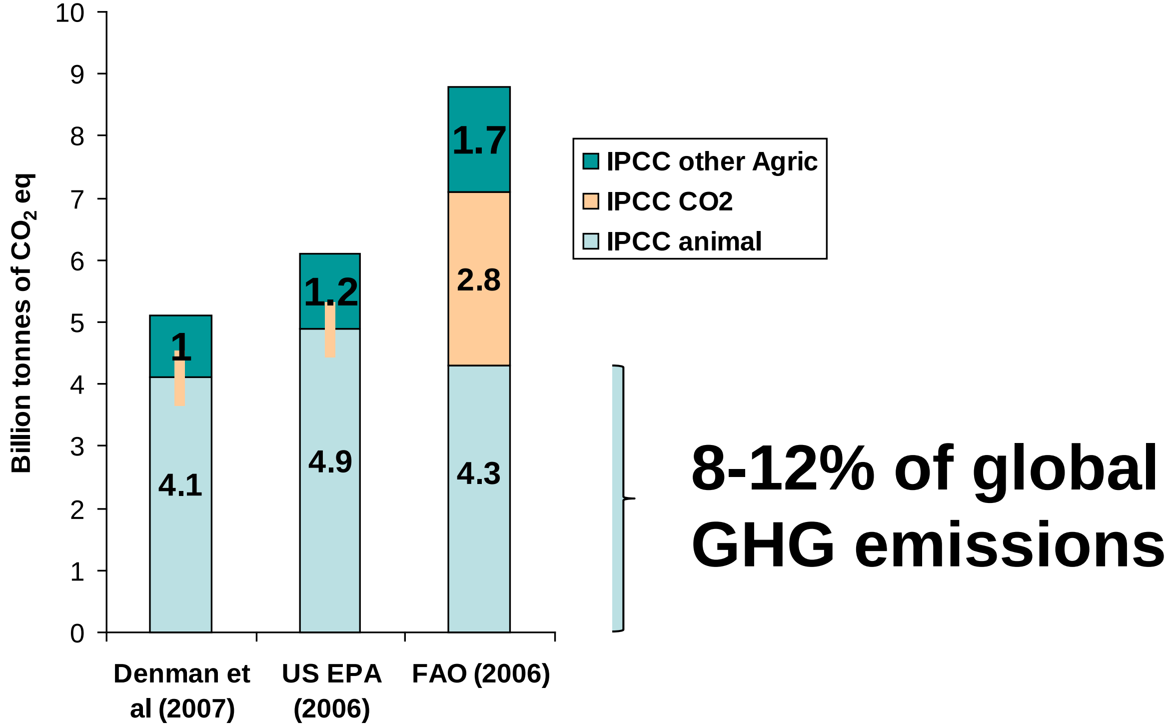
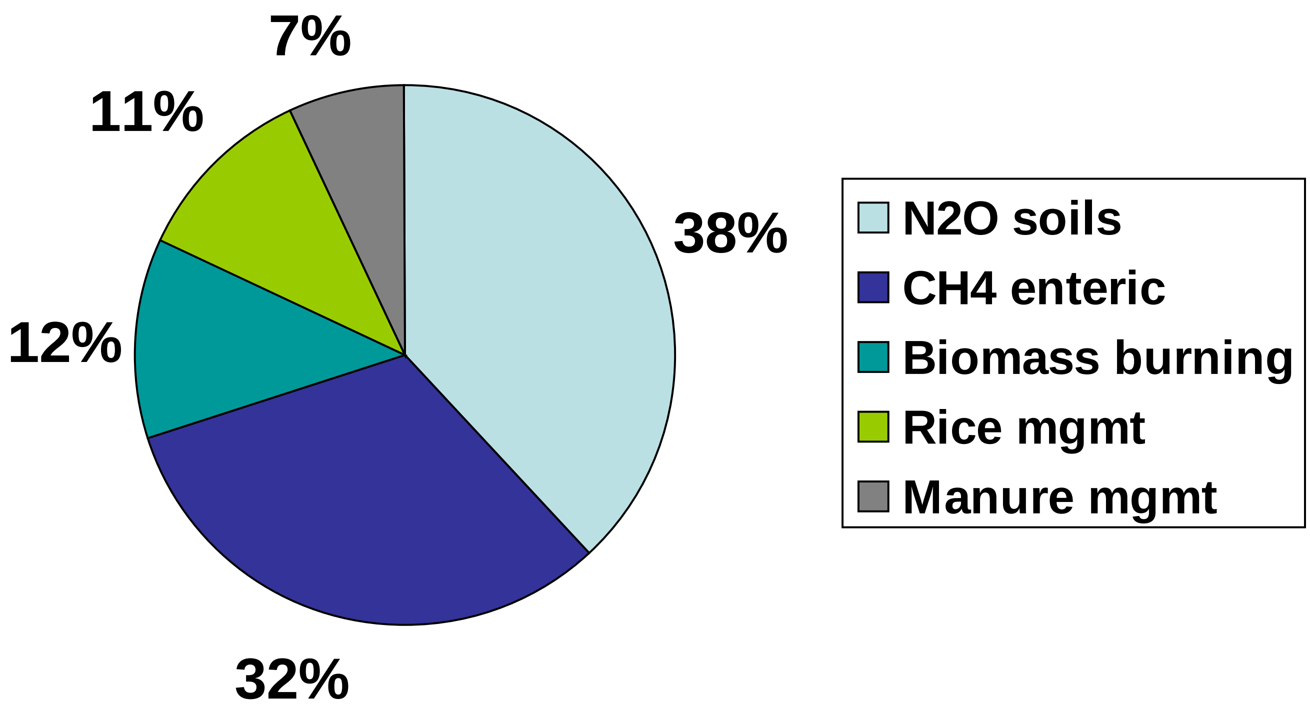


Figure from F. O'Mara, 2010 GGAA

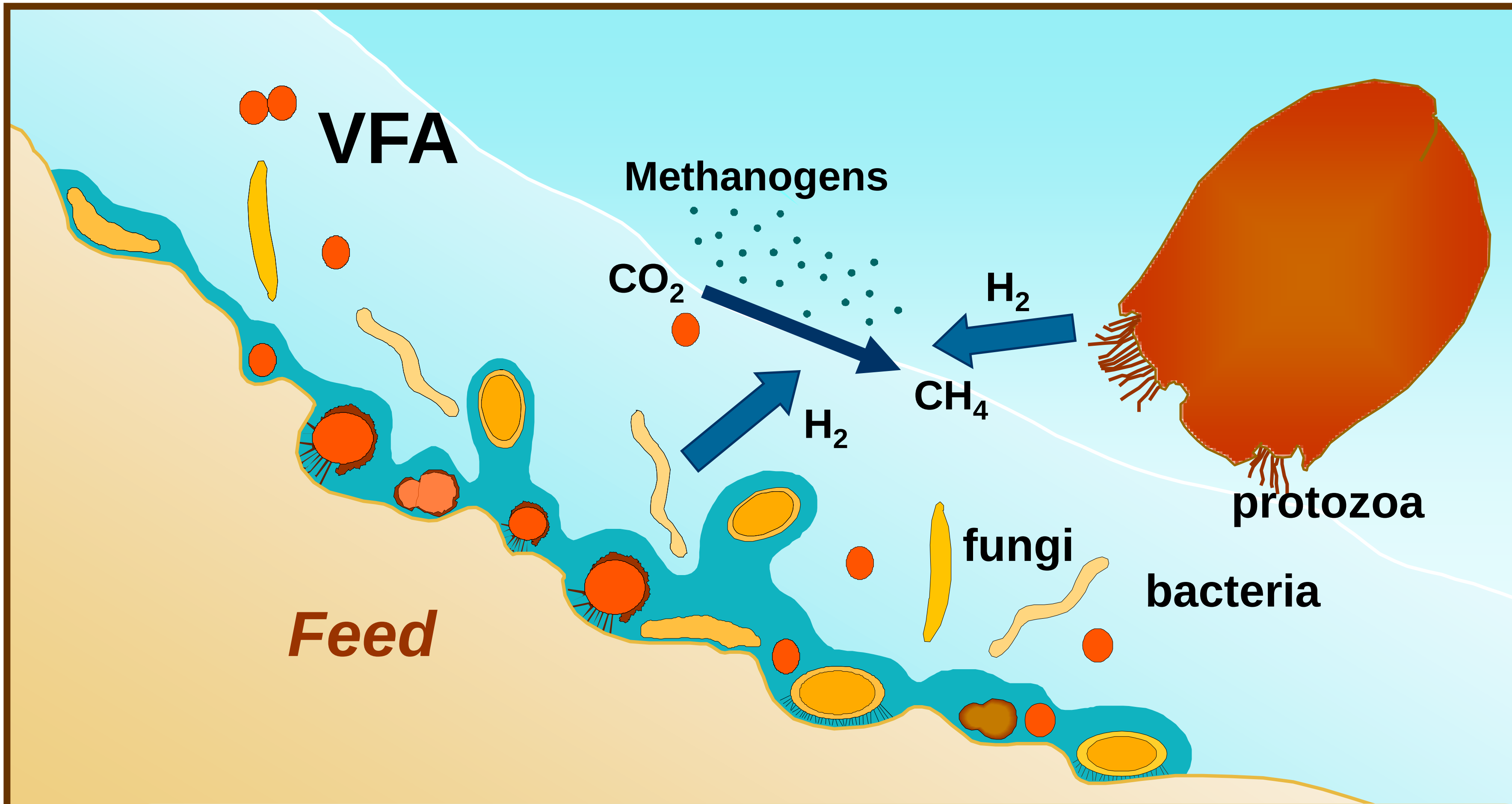
Global agricultural emissions (2005) (IPCC sources)

5-7 Billion tonnes CO_2eq/year



Source: US EPA (2006)

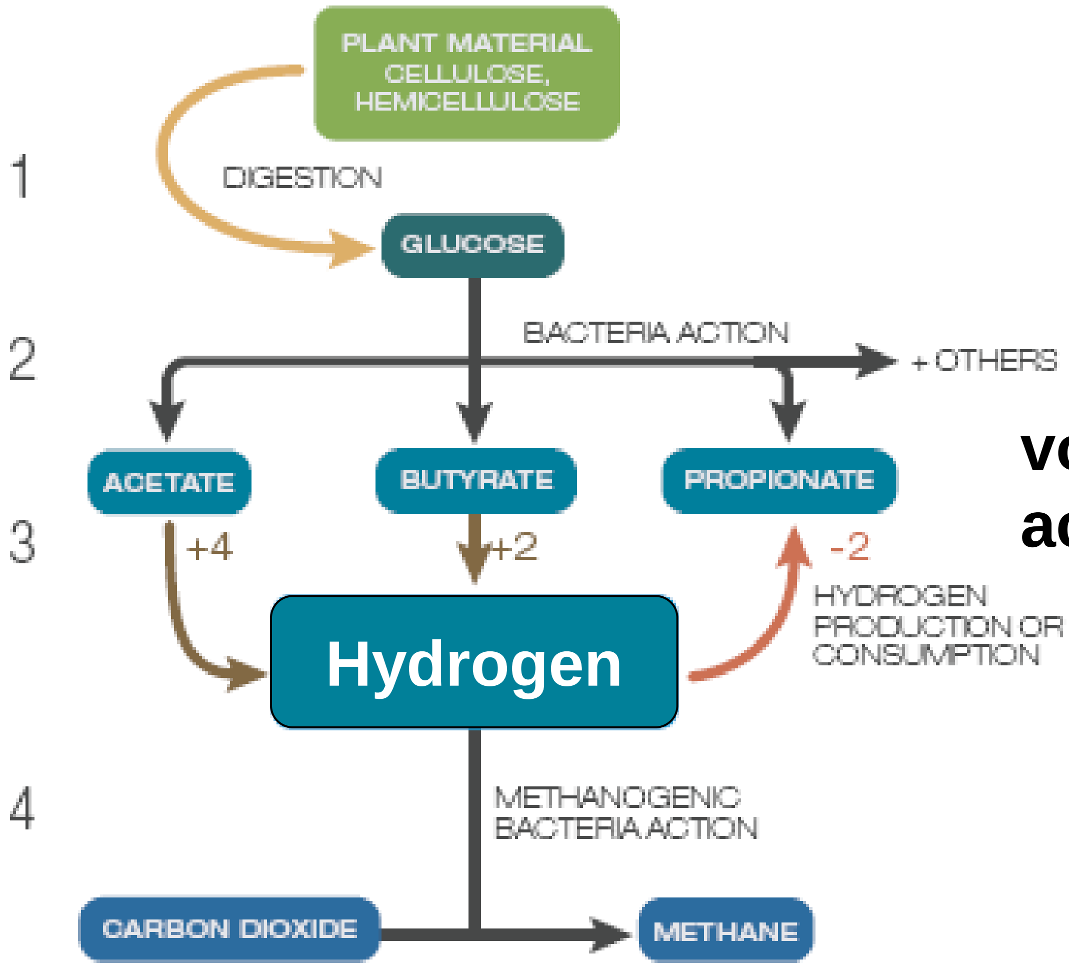
Methane production is a microbially driven process



Methanogenesis

$$4H_2 + 2CO_2 \longrightarrow CH_4 + 2H_2O$$

Production of methane in the rumen

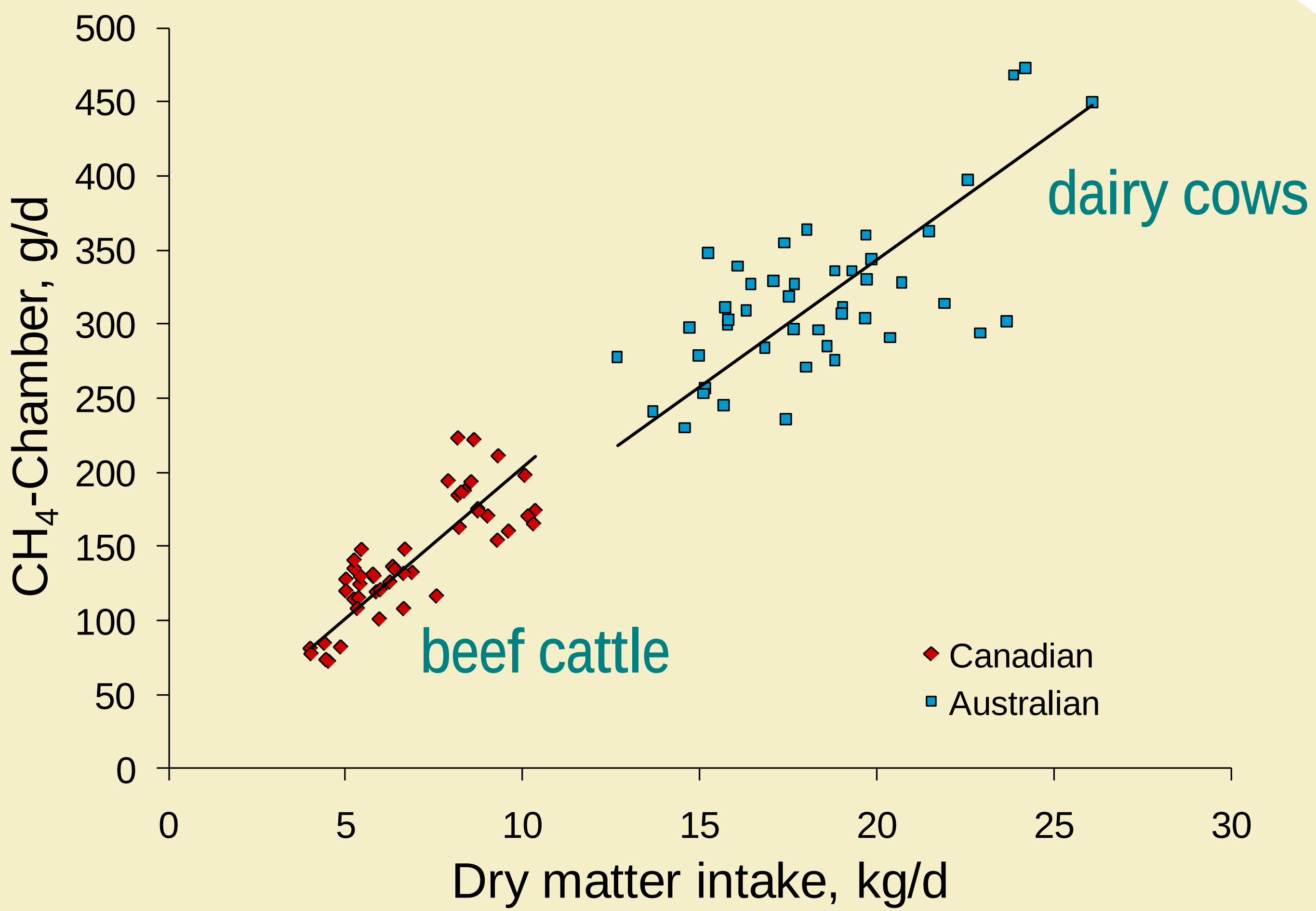


volatile fatty acids

Methane formation in the rumen

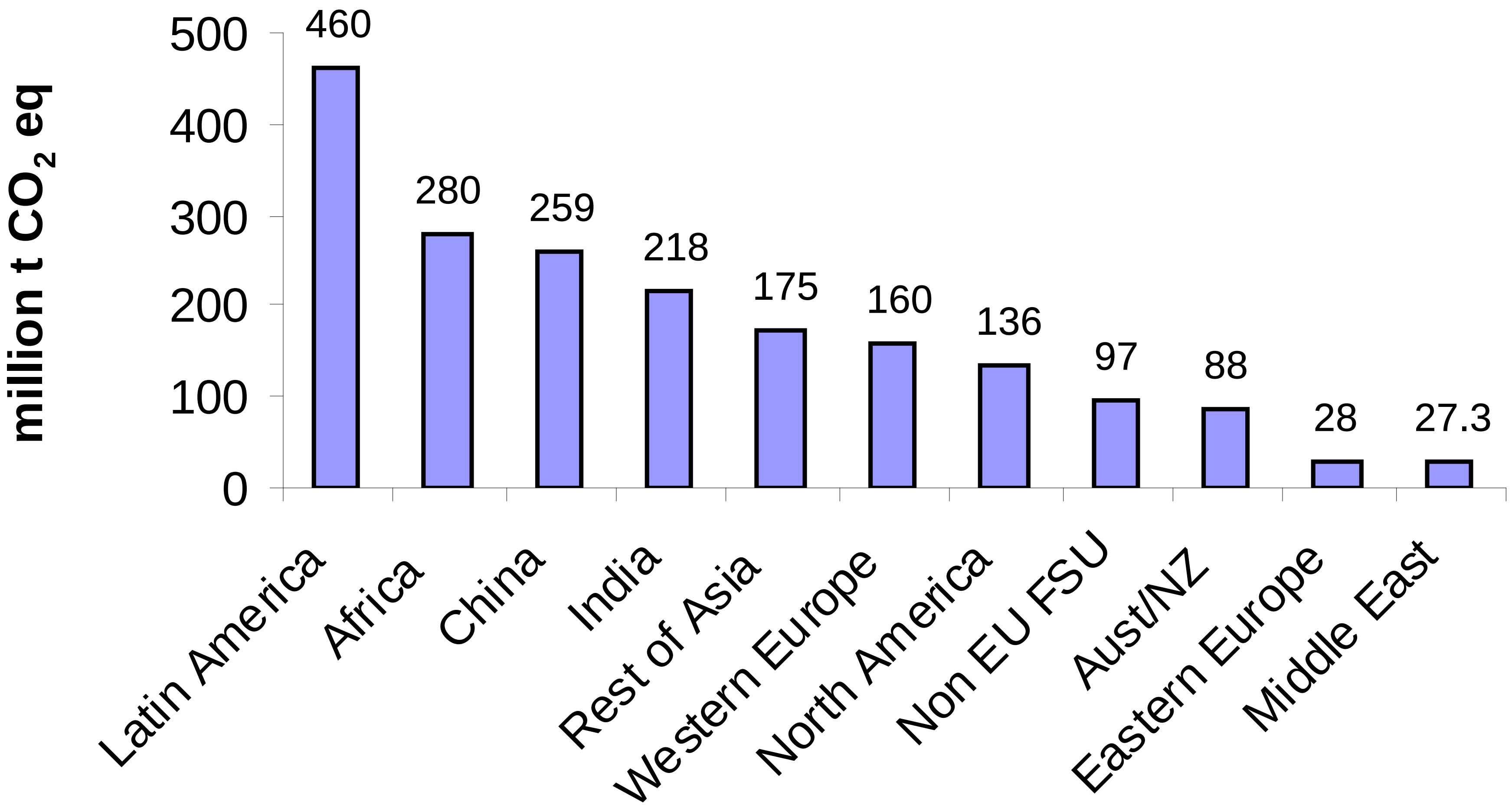
- 2 to 12% of the gross energy consumed is converted to methane (Ym, methane conversion factor)
- 6 - 8% forage based diets
- 3 - 4% feedlot finishing cattle

Methane emission and dry matter intake



Grainger et al. 2007. J. Dairy Sci.

Enteric methane emissions by region



As summarized by F. O'Mara, 2010 GGAA

A Research Approach

Outline

- Contribution of livestock to GHG emissions
- Measuring emissions
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- “Holo”-istic approach – whole farm modeling
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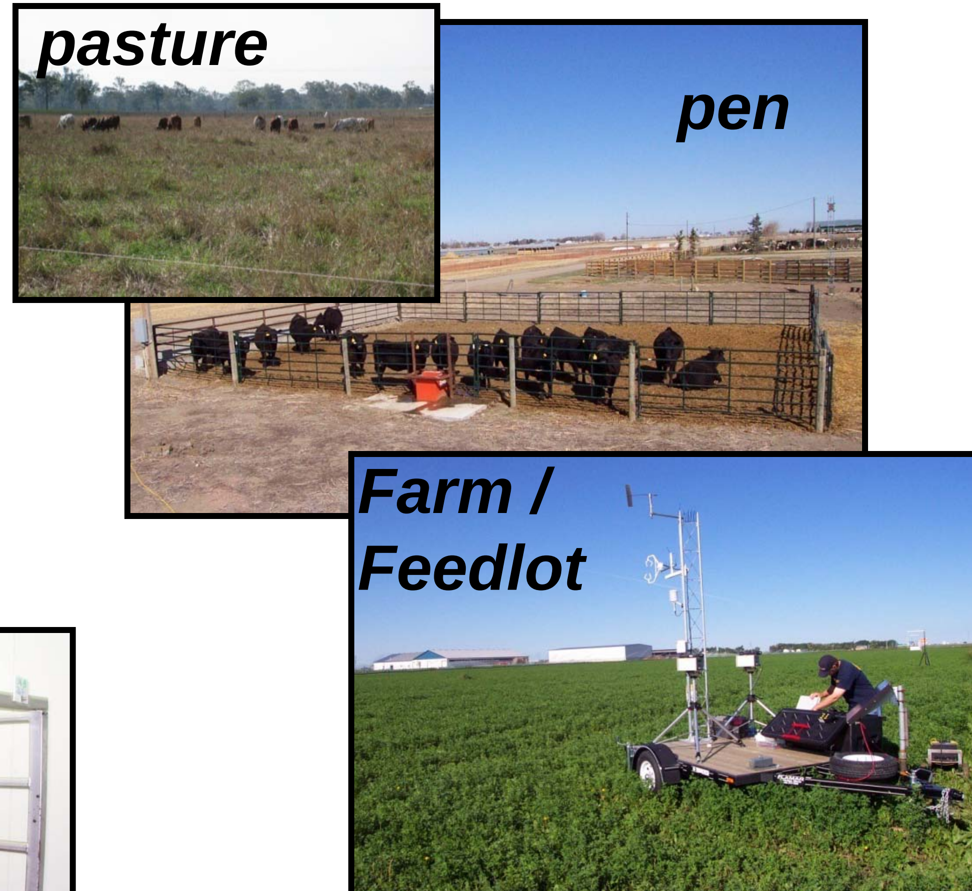
Types of Emission Measurements

Tracers



Dispersion
(methane and ammonia)

Chambers

Measuring using SF_6 tracer method

(Johnson et al. 1994)

Controlled release of trace gas in the rumen

$$\left[\frac{Emission}{Concentration}\right]_{methane} = \left[\frac{Emission}{Concentration}\right]_{tracer\ gas}$$

Caution … SF_6 tracer method

Measures individual animal emissions …

- need to know within- and between-animal variability to understand treatment effects
- requires knowing feed intake for individual animals
- variability high (10-18%)

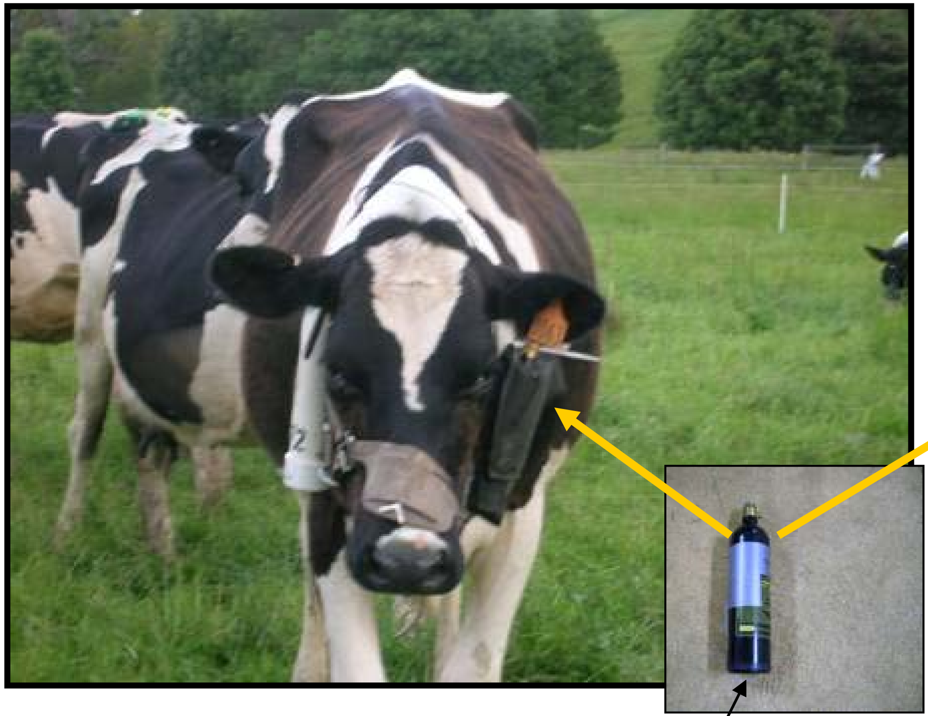
Can be used for grazing … but

- measuring feed intake is difficult

Problem with gas leakage from cannulated cattle

Alternative tracer method

Individual animals, Dr. David Griffith
University of Wollongong, Australia



Tracer release inside a barn with downwind measurements

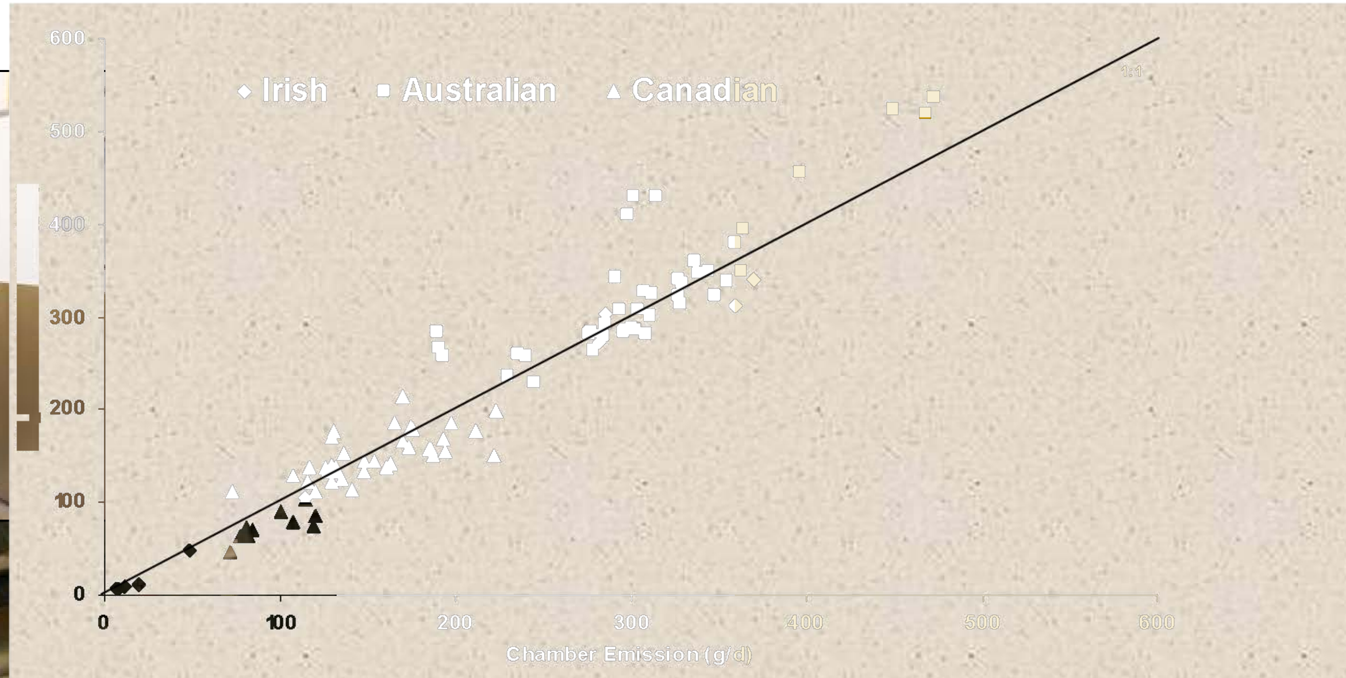
Concentrations measured downwind

$$\left[\frac{Emission}{Concentration}\right]_{methane} = \left[\frac{Emission}{Concentration}\right]_{tracer\ gas}$$

Methane Emissions using Animal Chambers (the gold standard)

- Oils
- DDG
- Oil seeds
- Acids
- Ionophores
- Grain/Forage
- Essential Oils
- Yeasts
- Forage type

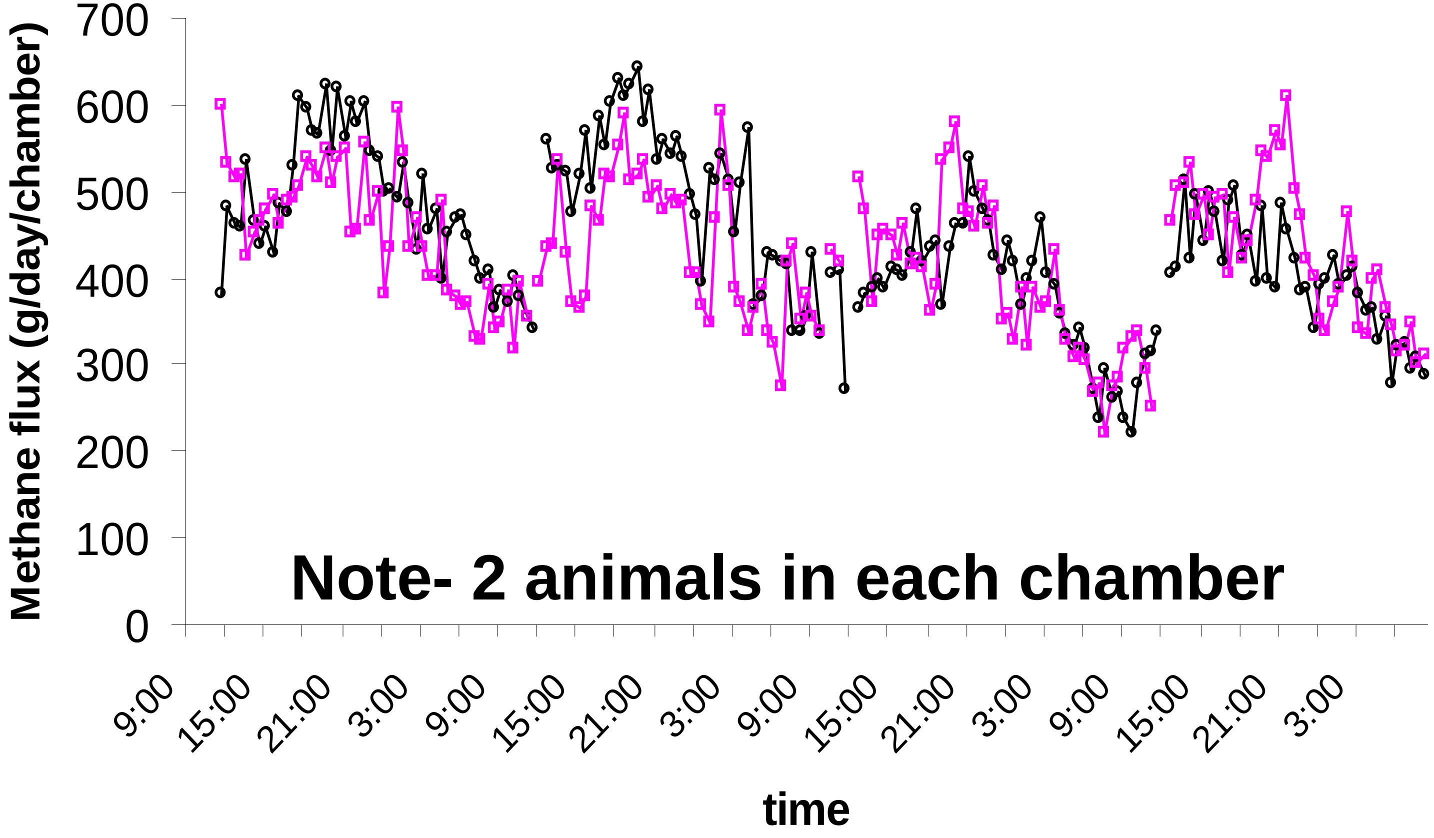
SF6 Tracer vs Chamber Emissions



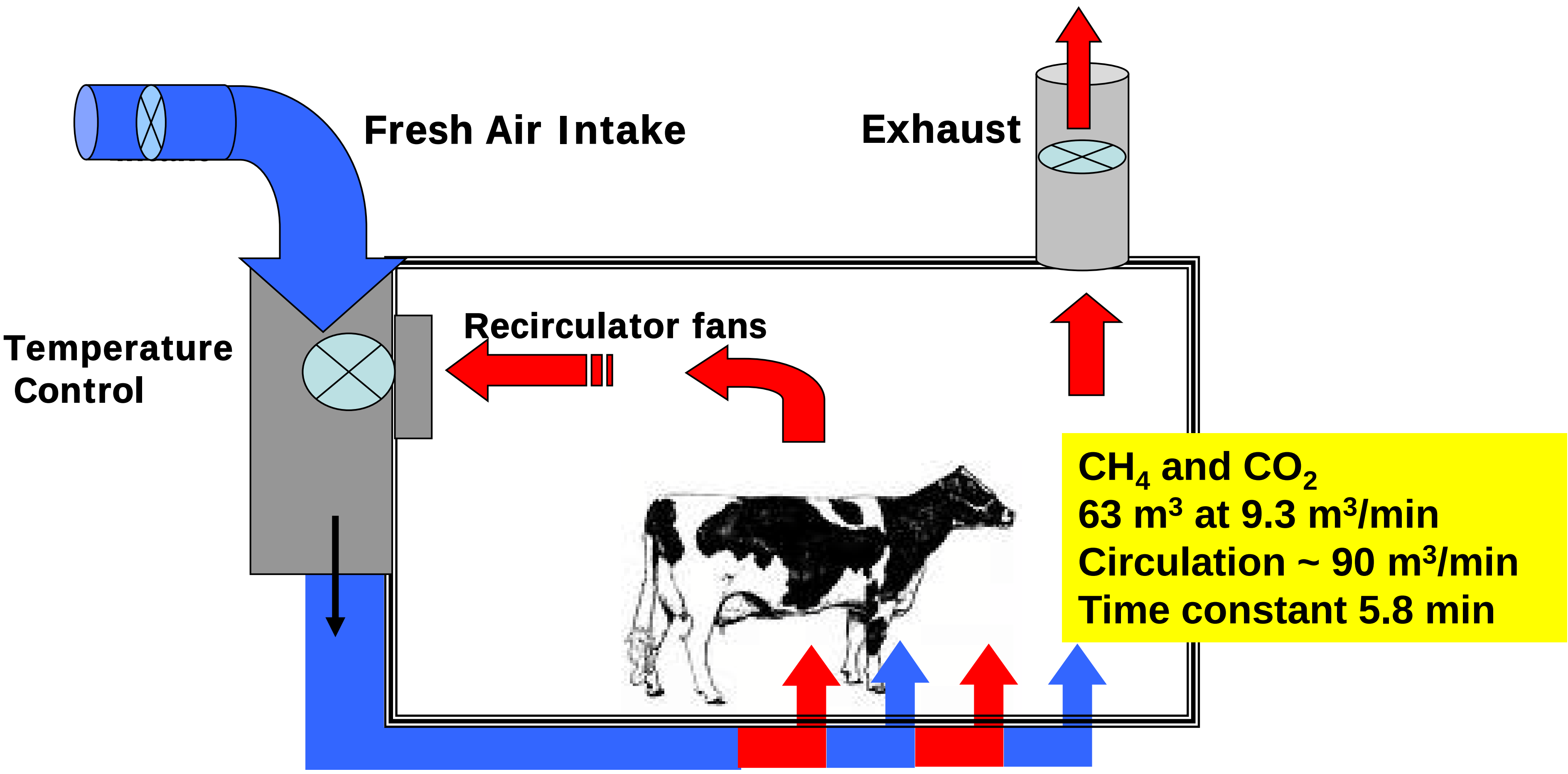
Grainger et al. (2007)

McGinn et al. (2007)

Methane Emissions from Animal Chambers - doubling emission following feeding



Lethbridge animal chambers

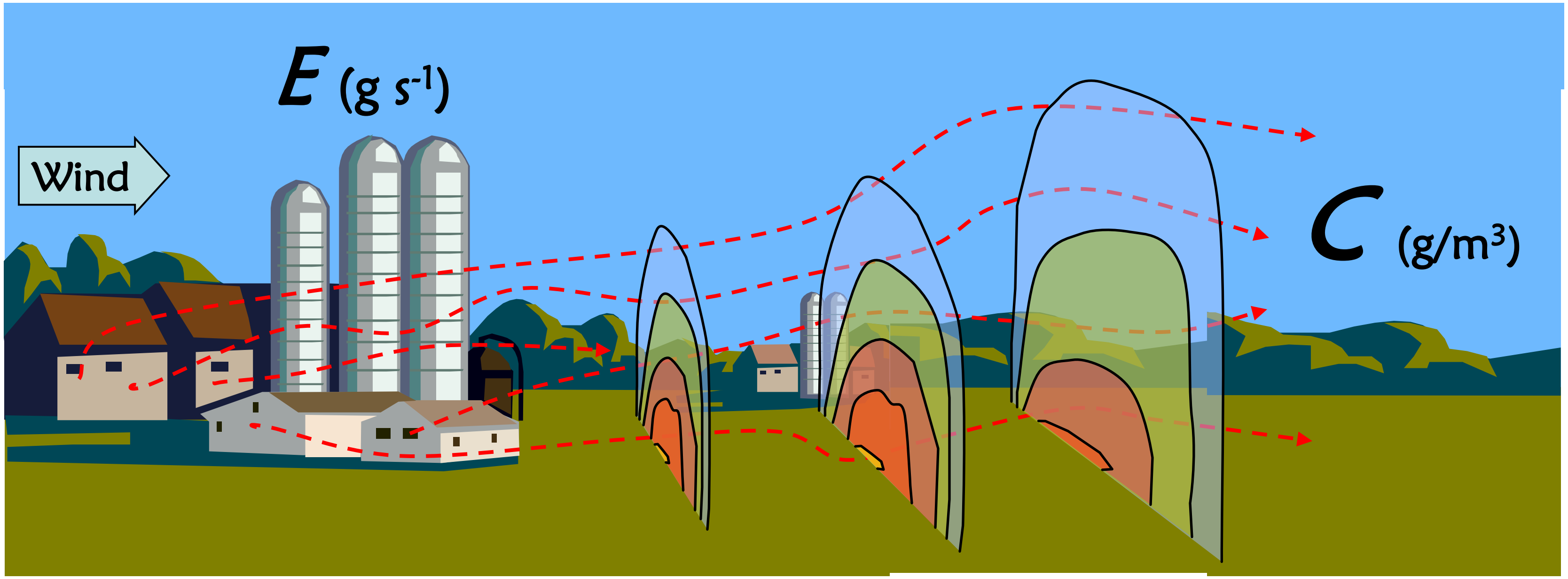


Aarhus University (Denmark)

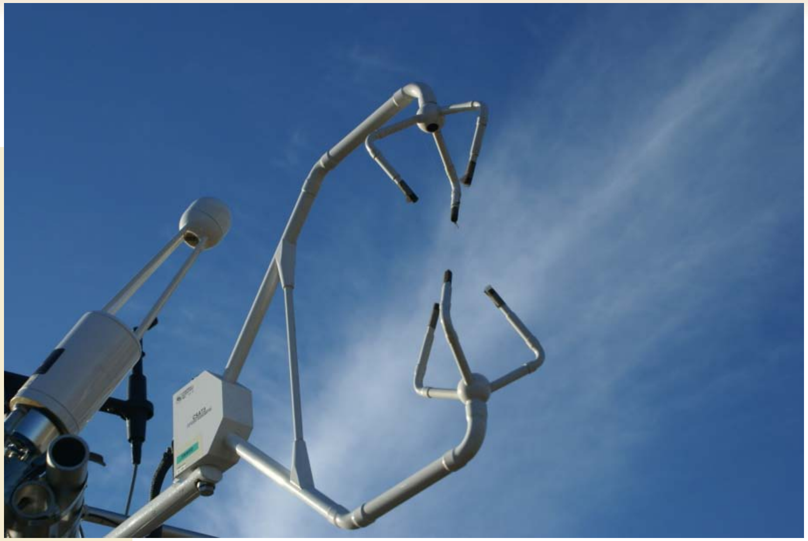
Anne Louise Frydendahl Hellwing

Modeling the gas plume dispersion

Dispersion model relates concentration *C* to emission rate *E* … measure *C* and the model can then infer *E*



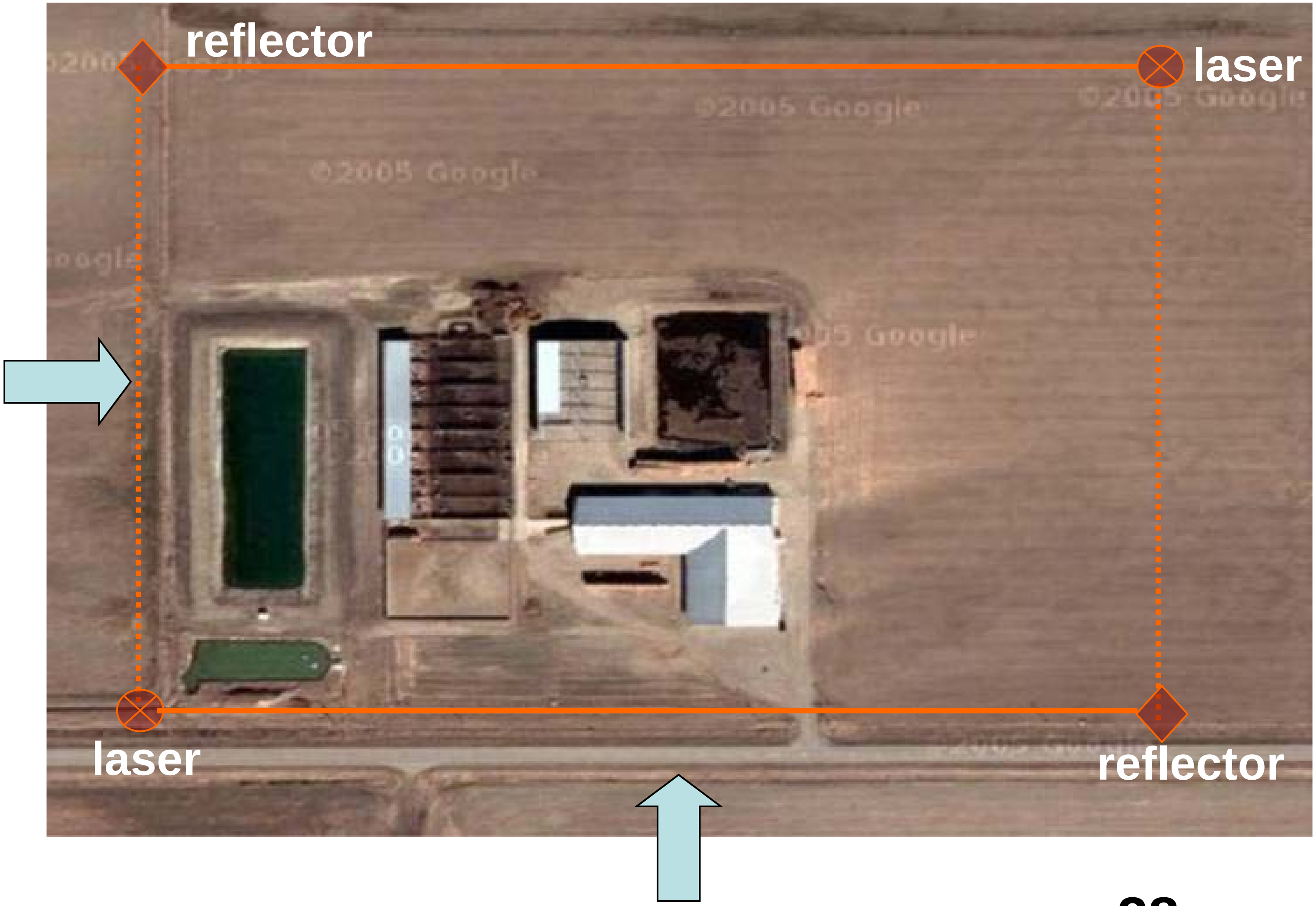
Sensors



Mixing capacity of air

Concentration using open-path lasers and FTIR (7 gases includes N_2O)

Example at a Dairy Farm



Dairy Farm Methane Emissions

	----------FARM ----------		
Methane (g/cow d)	405	442	448

Methane Emissions (g/cow/d)

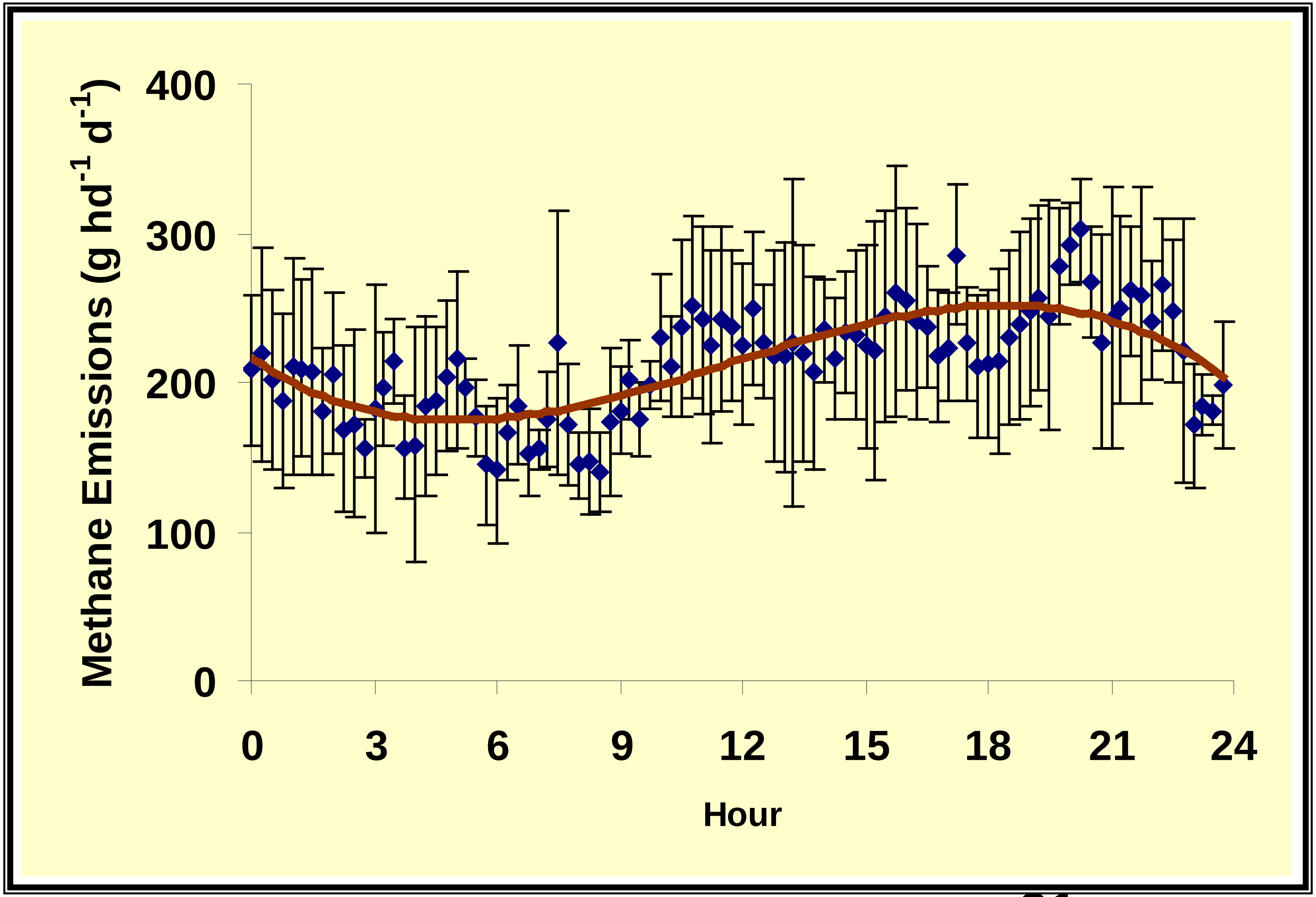
IPCC Tier I	323	(lactating cow)
New Zealand	330	(lactating cow)
Canada	400	(as high as 491)
German	300	(non-lactating cow)

Example at a Alberta Beef Feedlot

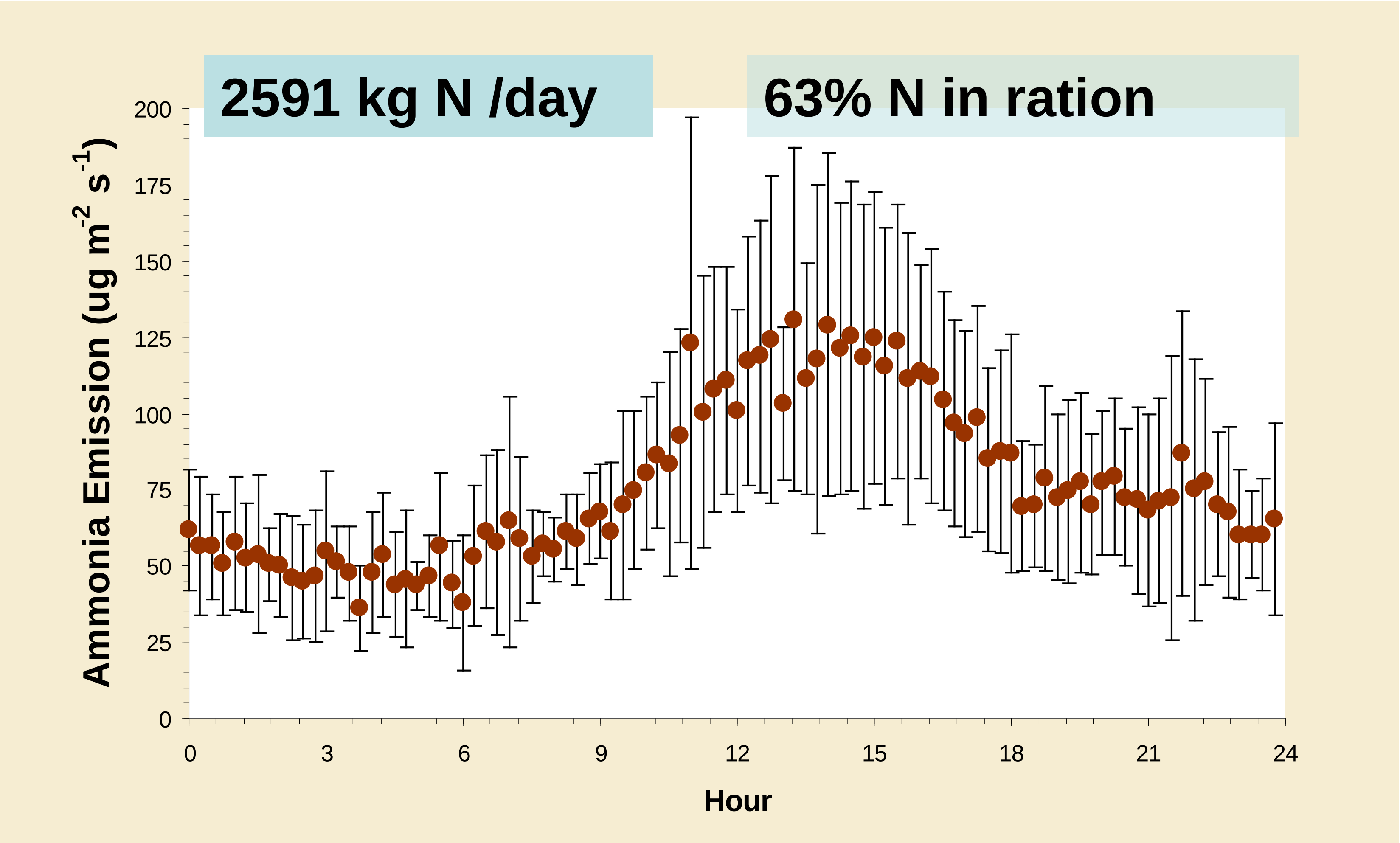
- 22,500 cattle
- Equipment set up in middle

laser

Pattern of methane emissions - feedlot



Beef Cattle Ammonia Emissions

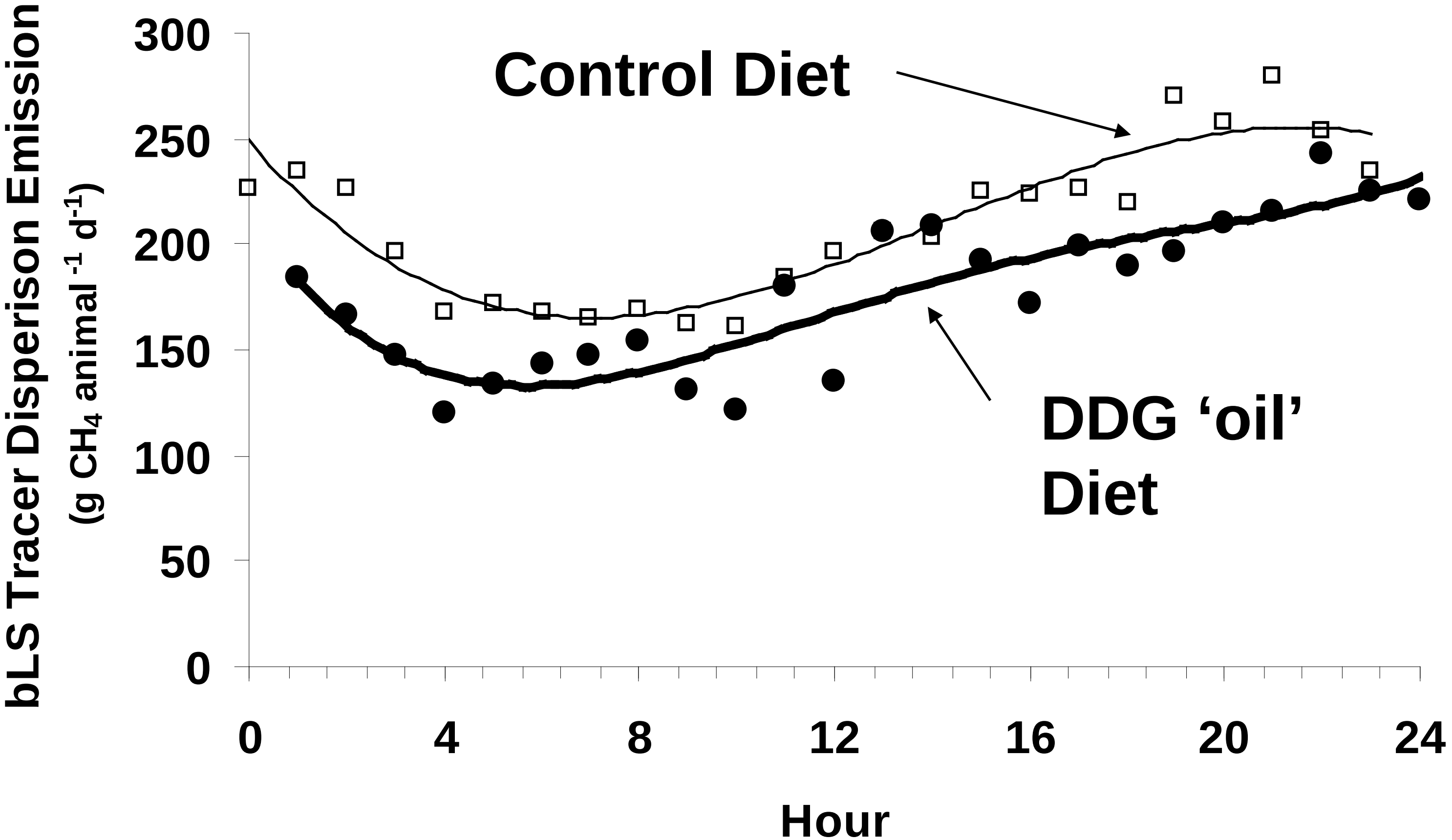


Lethbridge Isolated Pens – using GPS collars

Laser Concentration

SF_6 Tracer Method with GPS on collar

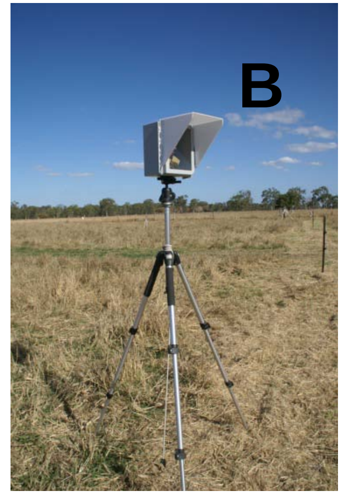
Precision of Dispersion Model for Dietary Trts



CSIRO Australia – Methane Pasture Study

A

B



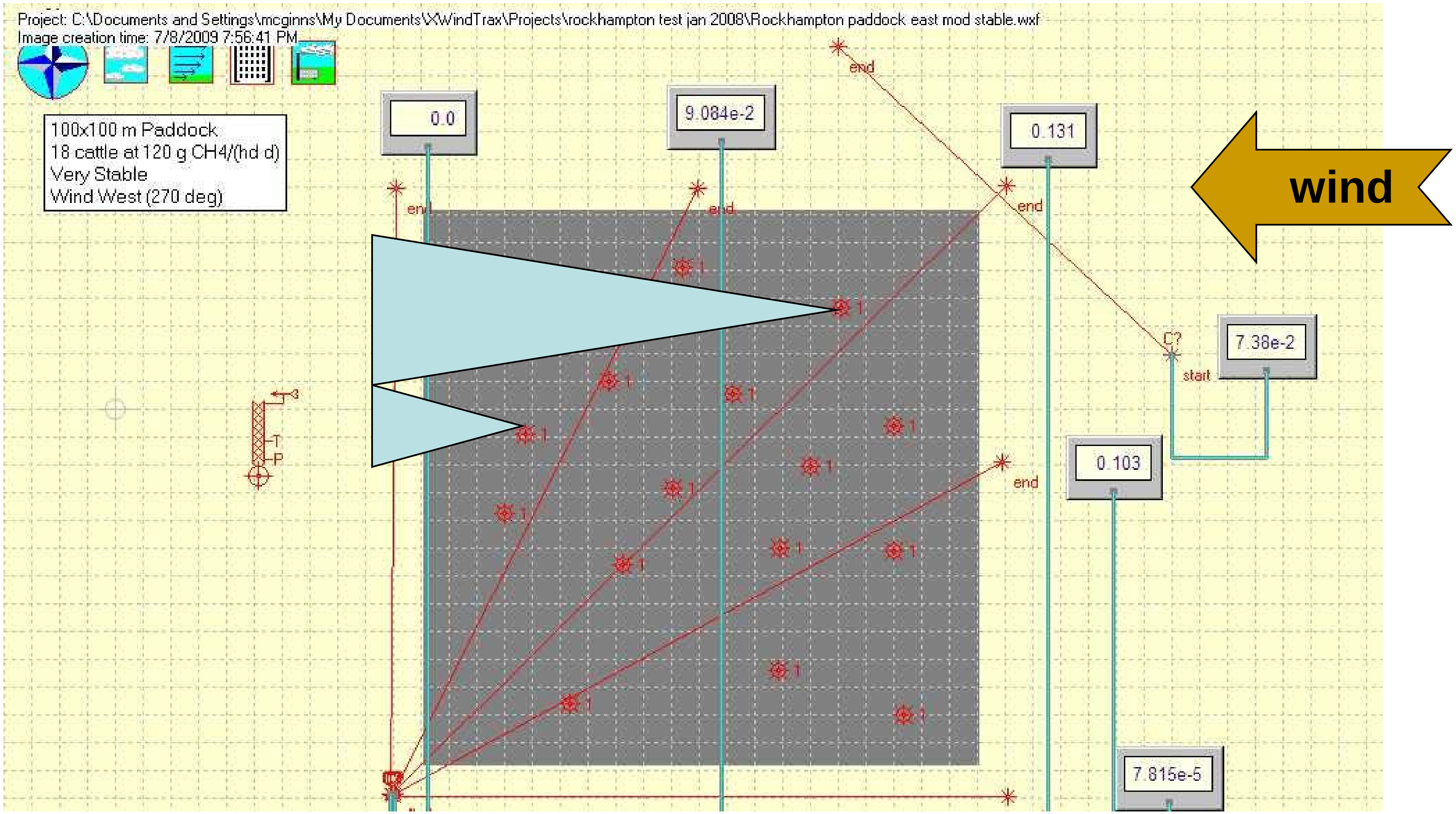
GRAZING CATTLE ARE A LARGE % OF THE GLOBAL METHANE EMISSIONS

- Mitigation ?

141 ± 147 g / (animal d)

(McGinn et al. 2011)

Dispersion of Methane from Grazing Cattle



Rangeland Study at Onefour Station

Final point

Team approach

Outline

- Contribution of livestock to GHG emissions
- Measuring emissions
- Potential for mitigation
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- Future perspectives

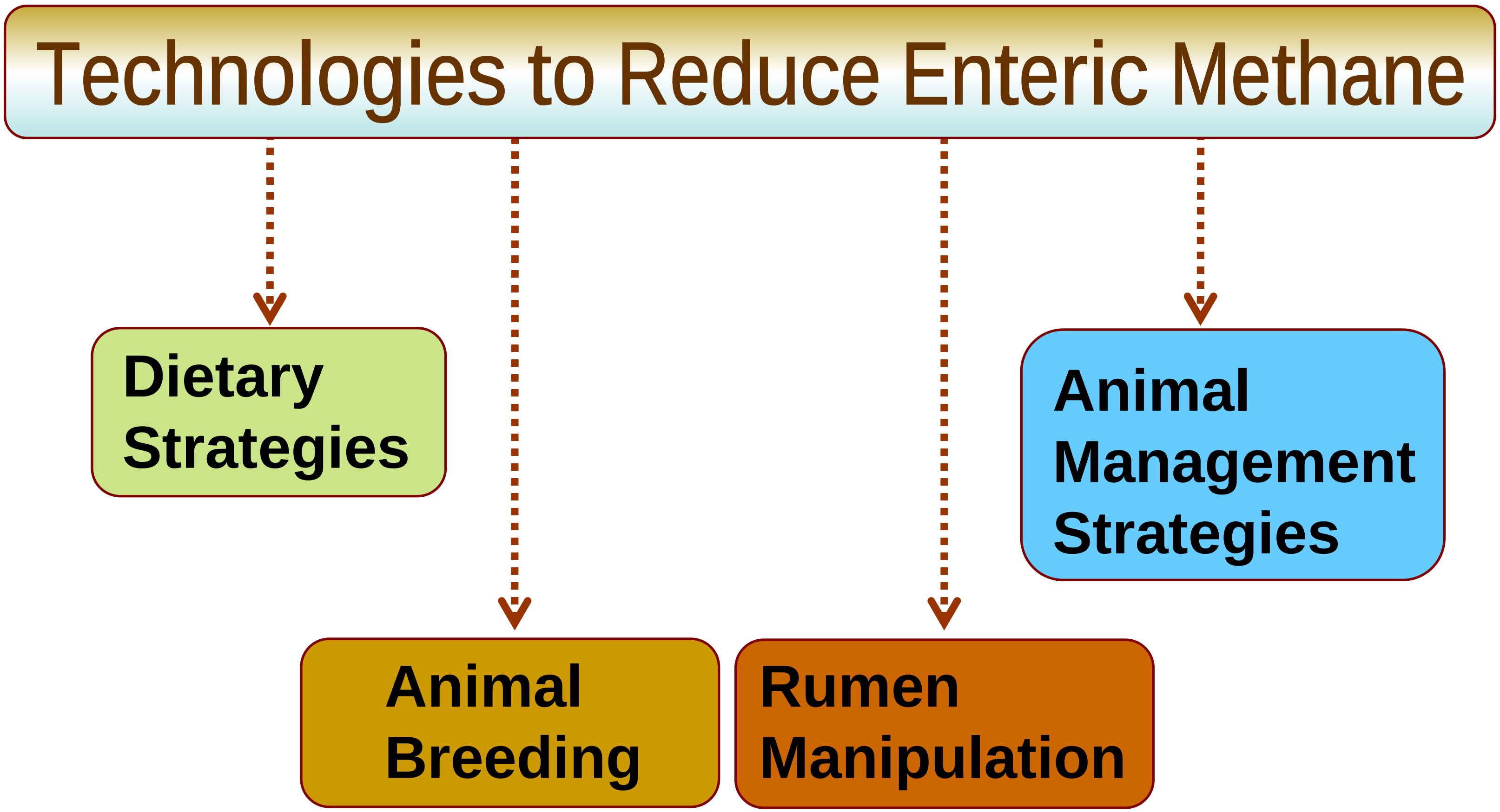
How can beef and dairy industries reduce methane emissions?

Mitigating Methane from Ruminants

- What is the metric?
  - g CH_4 / head / day (amount)
  - g CH_4 / kg dry matter intake (intensity)
  - g CH_4 / L energy corrected milk (intensity)
  - g CH_4 / ha (intensity)

efficiency

	Methane Mitigation Approaches		
	Reduce CH_4 formation in the rumen	Increase animal efficiency	Increase animal productivity
Feed intake	= ??	↓	↑
Animal product	= ??	=	↑
Methane g / head / day	↓	↓	↑
g / kg milk or meat	↓	↓	↓


Technologies to Reduce Enteric Methane
Dietary Strategies
Animal Breeding
Rumen Manipulation
Animal Management Strategies

Animal Breeding

1. High vs low methane emitters
   - 15% variability amongst animals in CH_4 / kg DMI (NZ)
   - Realistic given other breeding objectives?

2. Increased feed conversion efficiency
   - Animals that eat less (low RFI)
   - Approach used for beef cattle (CA, AU)
     - Higher efficiency cattle produced 24% less methane/kg gain than less efficient cattle (Hegarty et al. 2007. JAS 85:1479)

Rumen Manipulation

- Alter rumen microbial ecology to reduce methane production in the rumen
  - Vaccine: animals develop antibodies to methanogens (AU, NZ)
    - Experimental, success unknown (15% reduction?)
  - Acetogens (bacteria that use H_2 to form acetate)
    - Exist in the rumen at low numbers
    - Can we promote them in the rumen?
    - Exploratory, success unknown

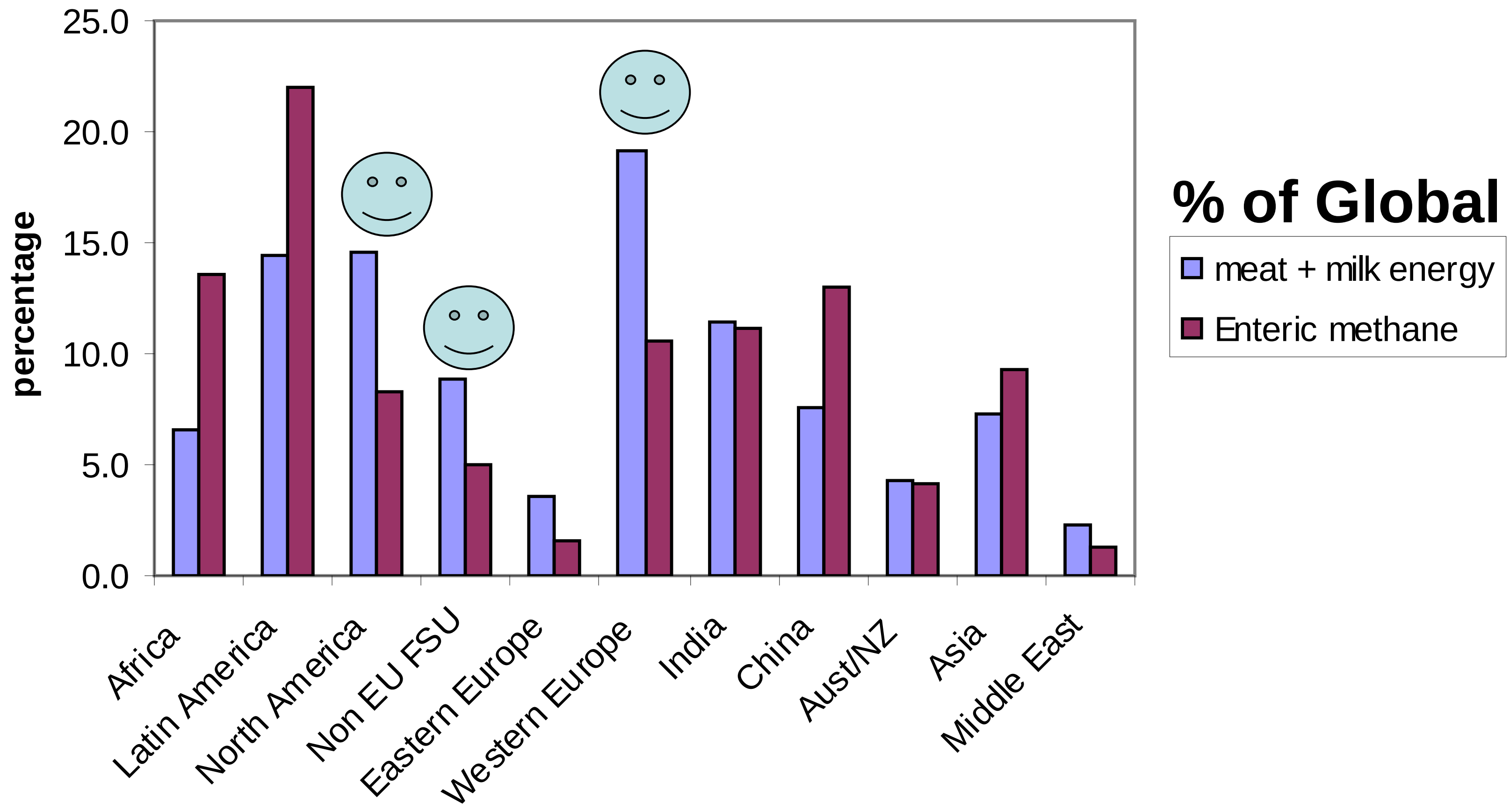
Animal Management Strategies

- Reduce inefficiencies
- Increase reproductive performance
  - Reduce number of open (non-pregnant) cows
  - Reduce number of replacement heifers (heifers contribute to emissions (20-30%), but not to product)
  - Increase longevity of mature cows
- Reduce number of days to market
- Others

Dietary Strategies

1. Increase animal productivity (higher inputs)

   lowers CH_4/kg meat or milk



Dietary Strategies

2. Decrease methane formation in the rumen
   - Diet manipulation and additives
   - Decreases CH_4/cow/day

I. Adding fat to the diet

Fats used in studies at Lethbridge	% crude fat
Whole cottonseed	23
Whole sunflower seeds	41
Crushed canola seeds	40
Crushed flaxseed	40
Tallow and animal fats	100
Sunflower oil	100
Corn and wheat distillers dried grains	15



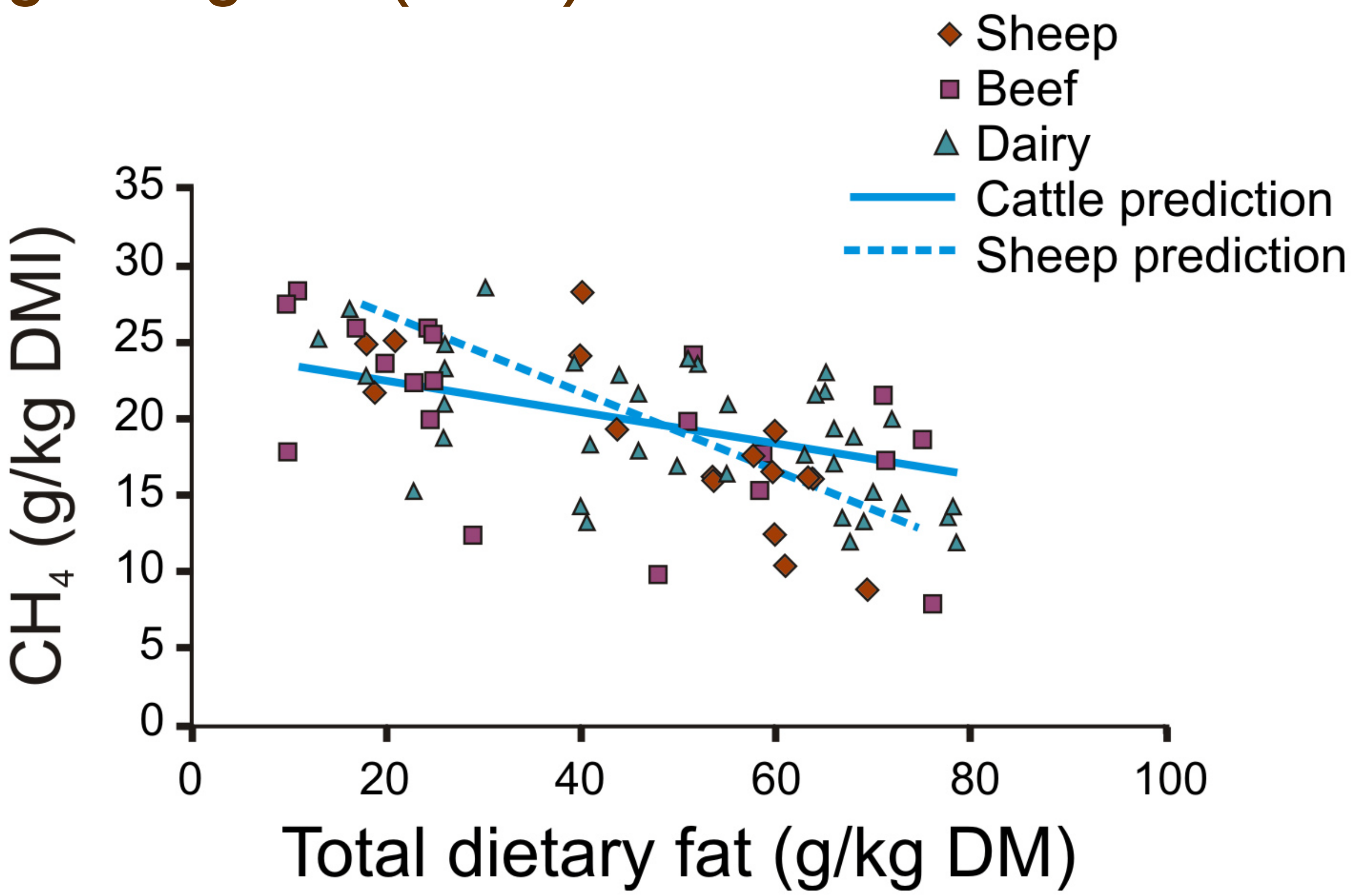

Adding ground oilseeds (3% added fat) to the diet of lactating dairy cows (Beauchemin *et al., 2009. J. Dairy Sci. 92: 2118*)

Methane	Contol	Sunflower	Linseed	Canola
DMI, kg/d	18.7 [c]	19.5 [ab]	19.0 [bc]	20.1 [a]
OM digestibility, %	63.5 [a]	52.0 [c]	58.1[b]	64.3 [a]
3.5% FCM	24.2	23.3	23.5	23.7
CH_4, g/d	293 [a]	264 [b]	241 [b]	265 [b]
CH_4, g/kg DMI	16.3 [a]	14.6 [ab]	13.4 [b]	13.7 [b]
CH_4, % GEI	4.9 [a]	4.3 [ab]	3.9 [b]	4.0 [b]

Control was a rumen inert Ca-soap

6% reduction/1% added fat

Meta-analysis – diets containing up to 80 g fat/kg DM (n=76)



Grainger and Beauchemin, AFST 2011

Meta-analysis – adding lipids to diet

Data for cattle (n = 59)

- Increase fat in diet
  - From 3 to 4% DM (4.7% ↓ in CH_4 yield)
  - From 3 to 6% DM (14% ↓ in CH_4 yield)
- No effect of
  - Form of fat (oil vs oilseeds)
  - Type of fatty acid(C12+C14, C18:1, C18:2, C18:3)
  - No effect of ingredient source (canola, coconut, linseed, soybean, sunflower)
  - Not enough data to conclude
- Future research

II. Feeding more grain (starch vs fiber)

- Feeding grain (starch) decreases methane (/d and /kg product)
- Need to conduct a life cycle assessment to examine entire farm GHG budget
  - Very much depends of the local agriculture
- Not consistent with niche role of ruminants of converting high fiber feeds to meat/milk

III. Forages

- ***Grain-based forages vs grasses***
  - e.g., corn silage; small grain silage
  - Higher starch content decreases g CH_4 / kg DMI
  - Often improves animal productivity, decreases CH_4 / kg meat (milk)
  - Higher cropping inputs (need LCA)
- ***Legumes vs grasses***
  - Forage legumes produce less methane
  - Legumes have lower fibre content, faster rate of passage from the rumen
- ***Improving forage quality***
  - Complicated!!!!
  - Harvesting at early maturity
    - Increases CH_4 g/d because animals eat more
    - Higher intake decreases CH_4 g/ kg DMI
    - Higher digestibility increases CH_4 g/ kg DMI
  - Improves animal productivity, decreases CH_4/kg meat (milk)

IV. Feed Additives (experimental)

- Tannins (bind protein)
  - Tannin-containing forages (e.g., sainfoin)
  - Extracts
    - quebracho trees, black wattle trees (*A. mearnsii*)
- Saponins (defaunation agents)
  - Yucca extracts (CA)
- Essential oils (anti-microbials)
  - Garlic
- Bacterial direct fed microbials
  - Promote propionate
- Feed enzymes
- Yeast

Enteric Methane Mitigation: What is feasible?

Reduction	Strategy
10%	Improved feed conversion efficiency through animal breeding
10%	Management: reduced replacements, better reproductive performance
10%	Increased animal productivity through nutrition
20%	Reduced methane formation in the rumen through diet (ex. oils, grain, forage source, additives)
50%	Additivity ?

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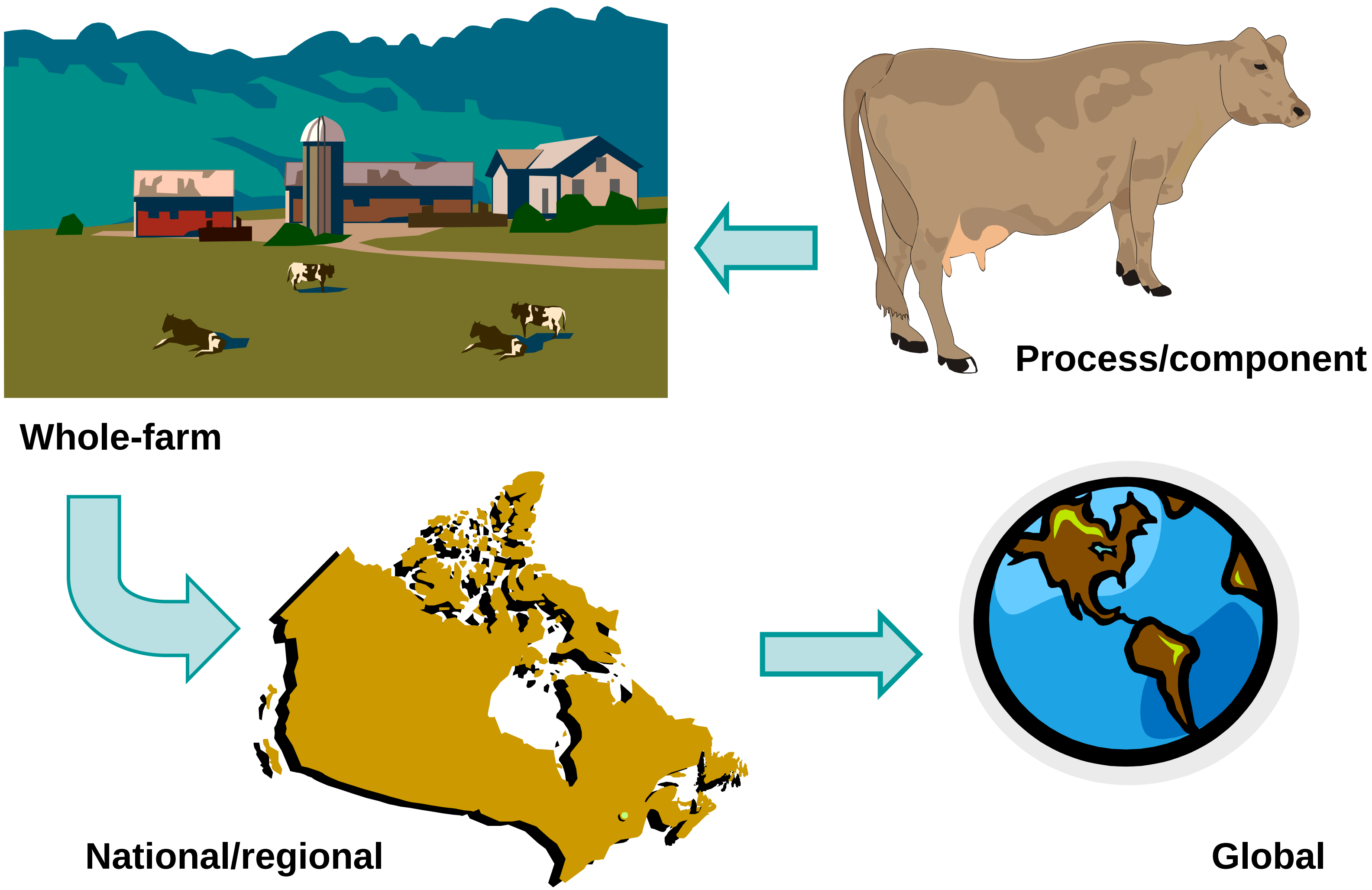
Country and Production Specific Mitigation Strategies

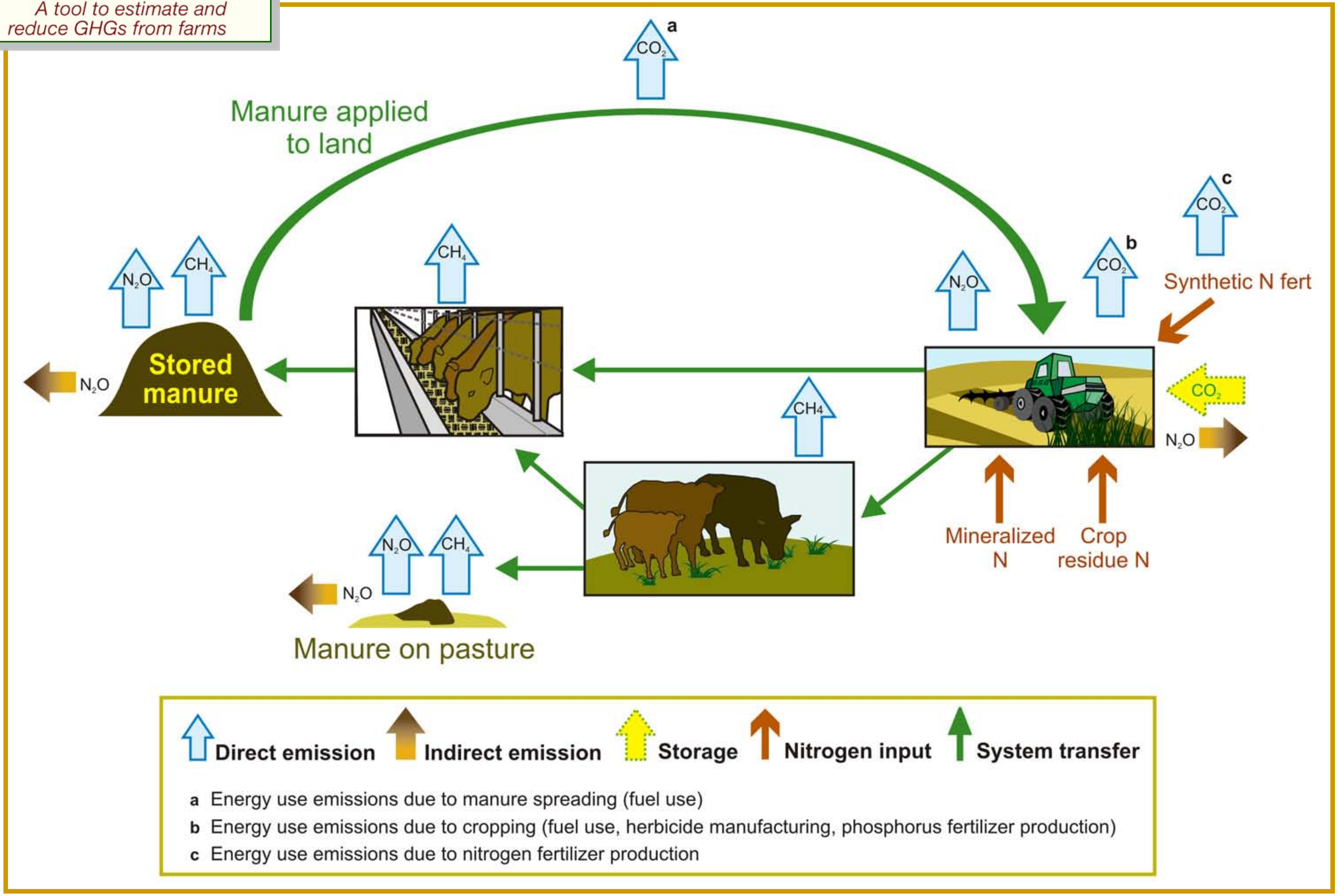
Tailored approach for each farm

Importance of GHG models

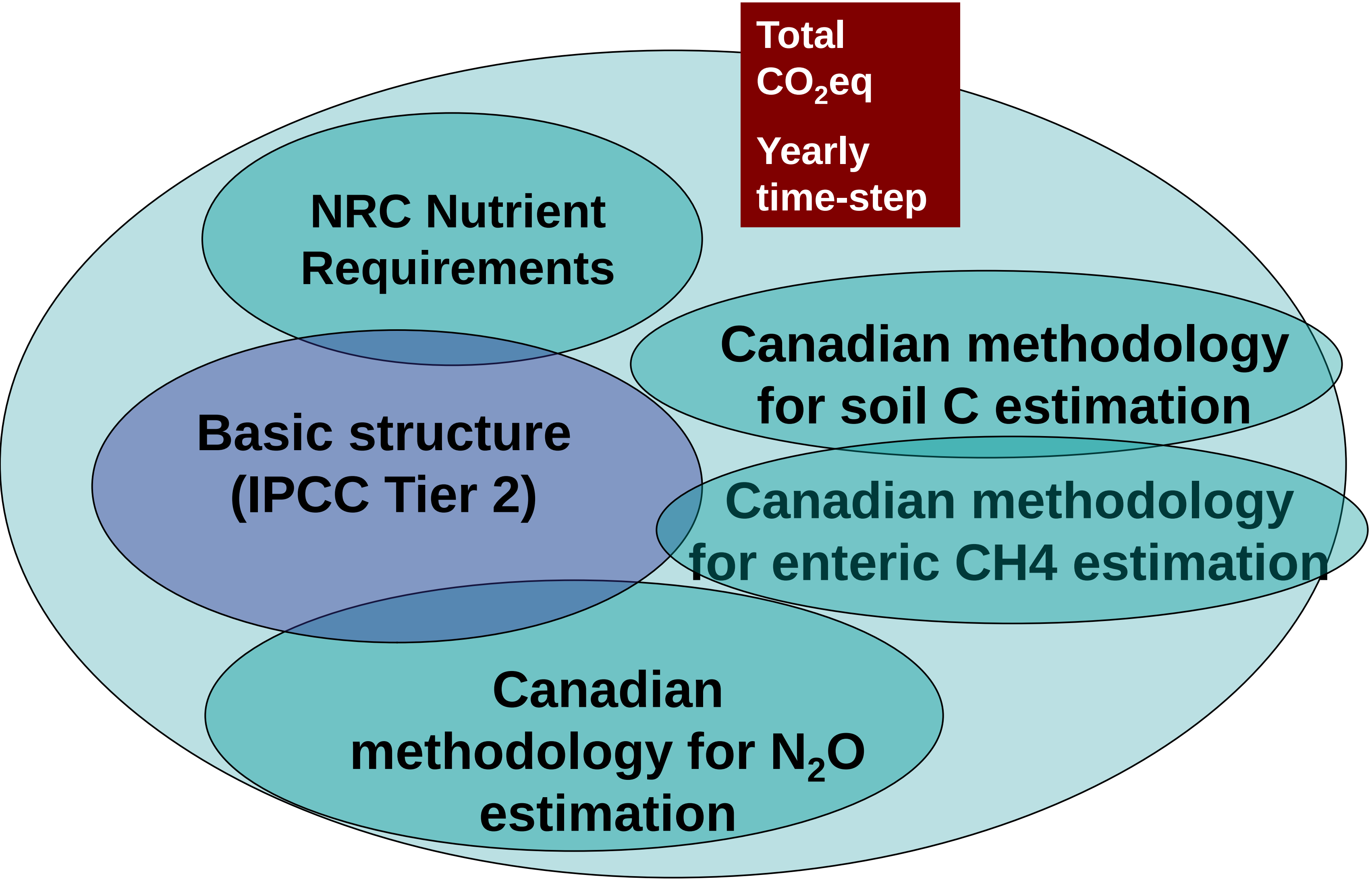


Holos
A tool to estimate and reduce GHGs from farms

Farm Based GHG Emissions



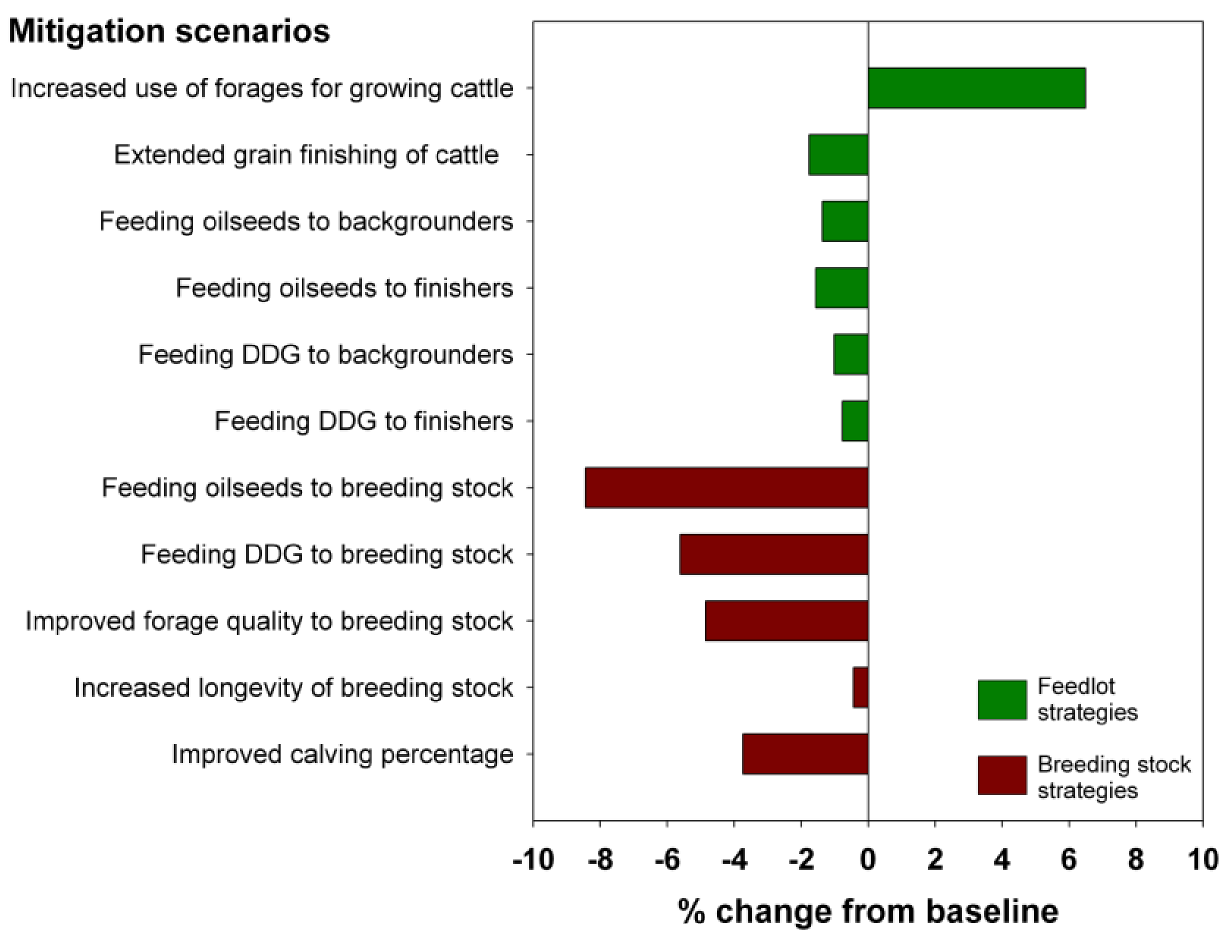
Holos – A tool to estimate and reduce GHGs from farms



Life Cycle Assessment of Beef Production in Western Canada (Beauchemin et al. 2010. Agric. Syst.)

- **8 year cycle**
- **All feed produced on the farm**
- **GHG emissions / kg of beef produced**

Mitigation of GHG for Beef Prodiction (LCA approach)



Percent change from the baseline emission = 21.73 kg CO_2e (kg beef carcass)$^{-1}$

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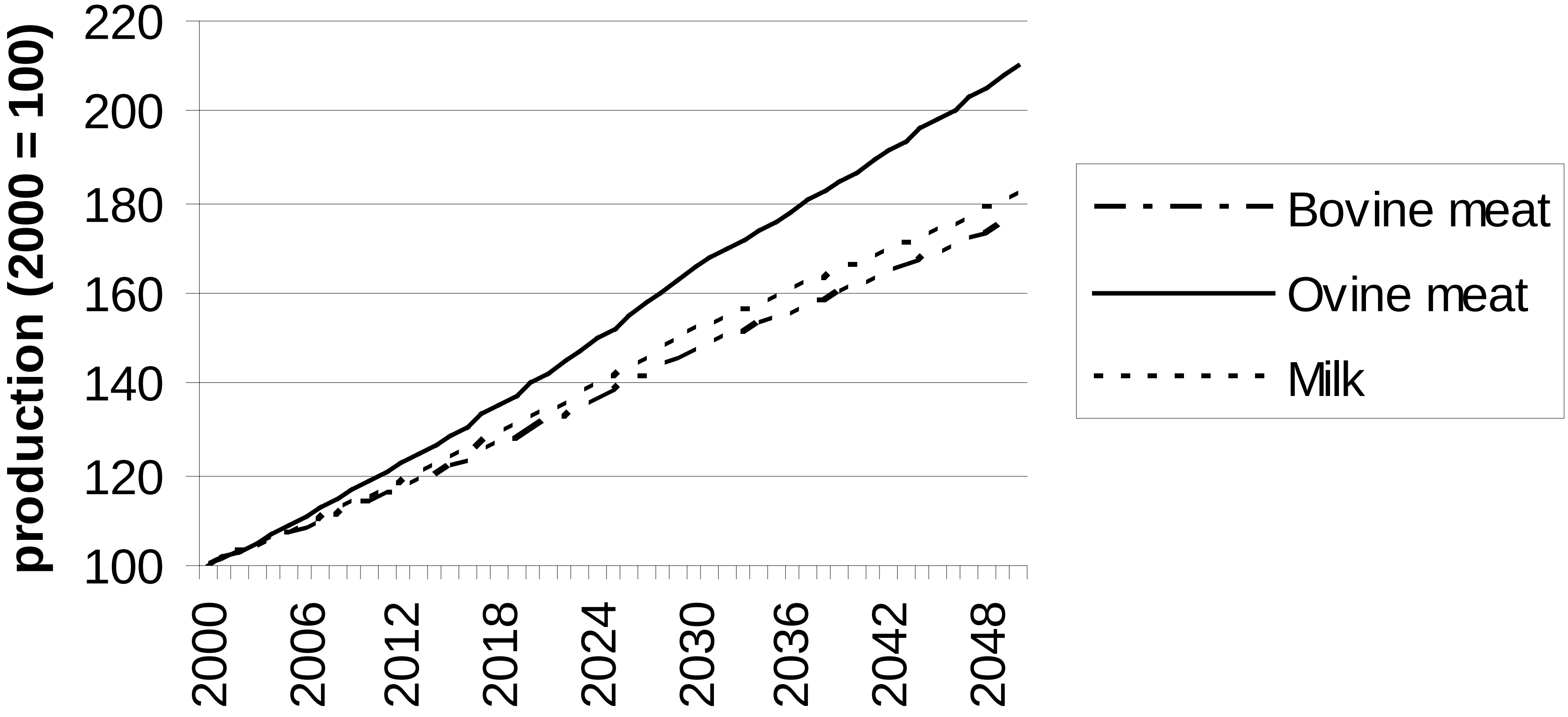
Projected growth of global milk and meat production

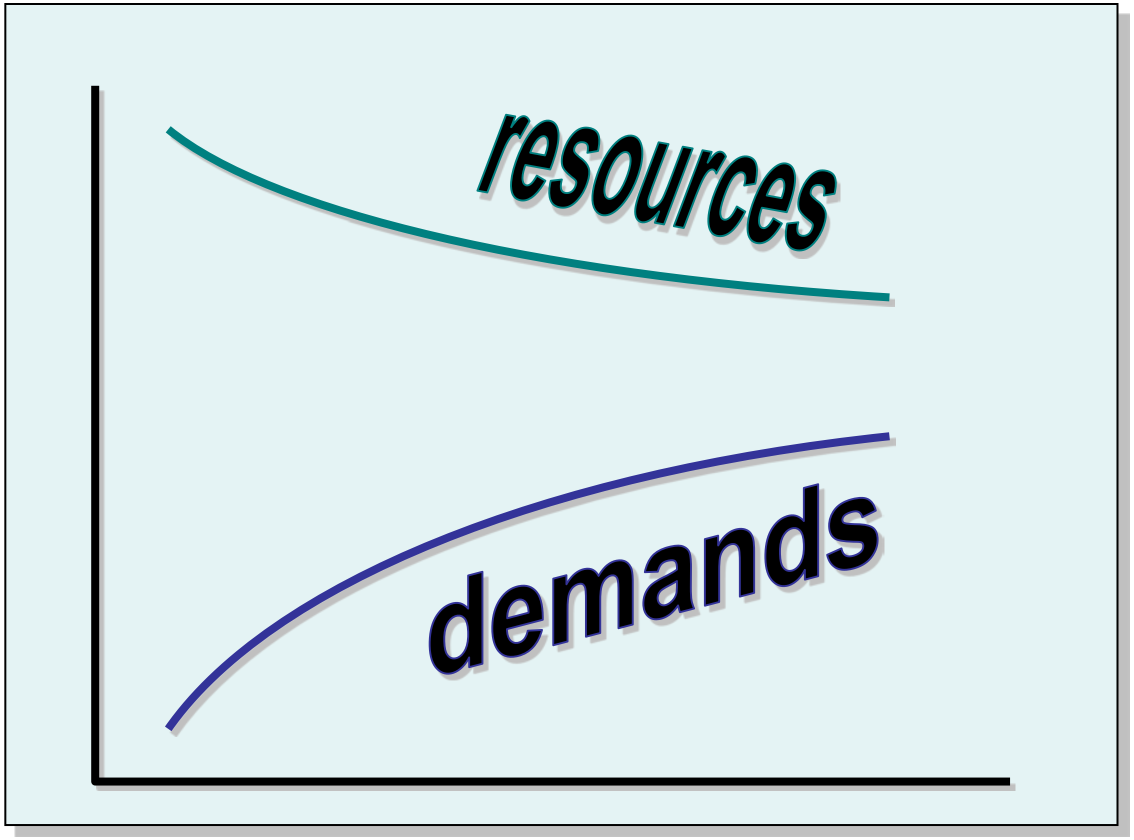


FAO (2006) as presented by F. O'Mara, 2010 GGAA

Future Perspectives for Livestock

"The Earth's vital signs are in a danger zone: human population and consumption stretch the capacity of the planet …"

Bernard 2010 **p25**

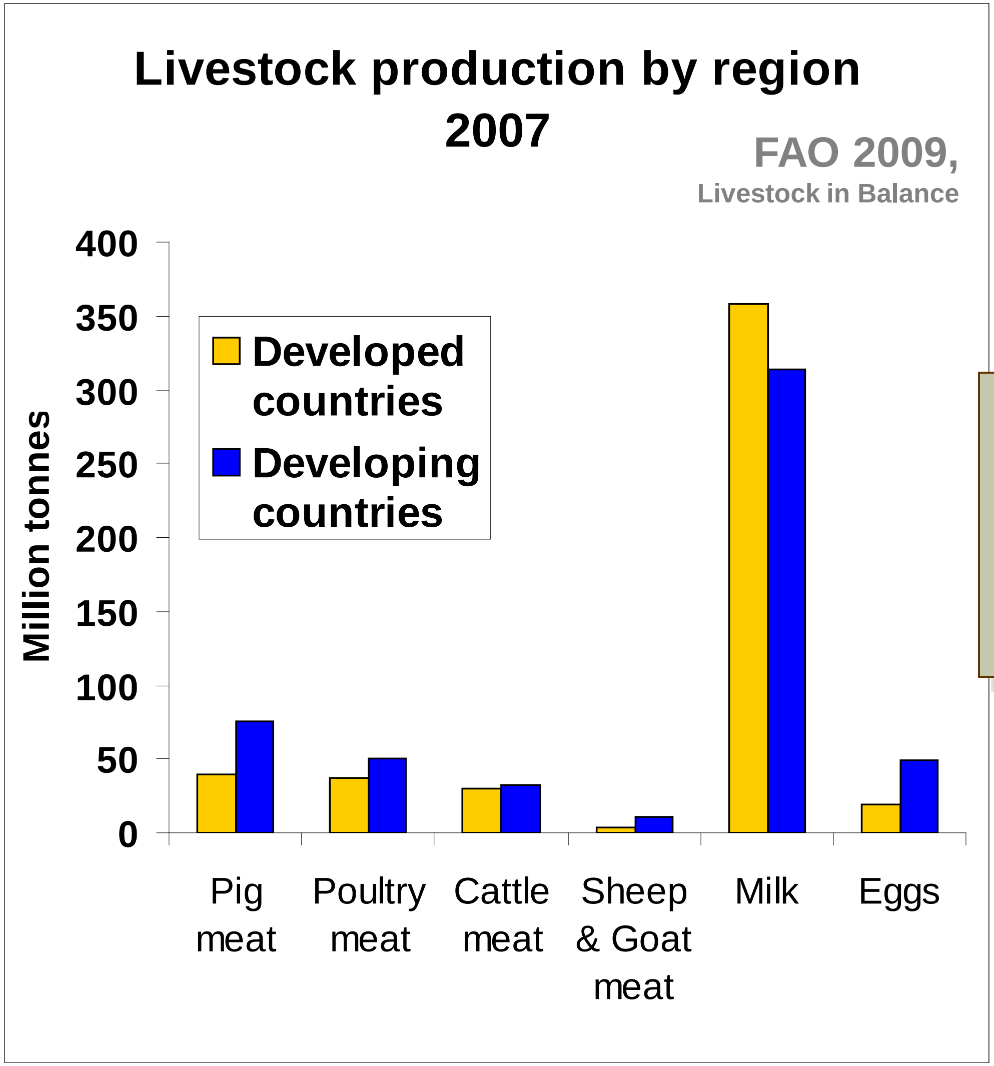


GHG Emissions Will Increase with Increasing Demand for Food

- Decreasing total GHG emissions from agriculture not likely
- Need to consider GHG efficiency
- “GHG viewed as investment” (H. Janzen, GGAA2010)

$$\text{efficiency} = \frac{\text{kg meat/milk}}{\text{tonne of } CO_2e}$$

Do we have GHG models and technology for the developing world?



The total demand for animal products in developing countries is expected to more than double by 2030.

Bruinsma 2003

GHGs are only one measure of environmental impact

- Need to expand our models to include other ecosystem services.

Ecosystem services:

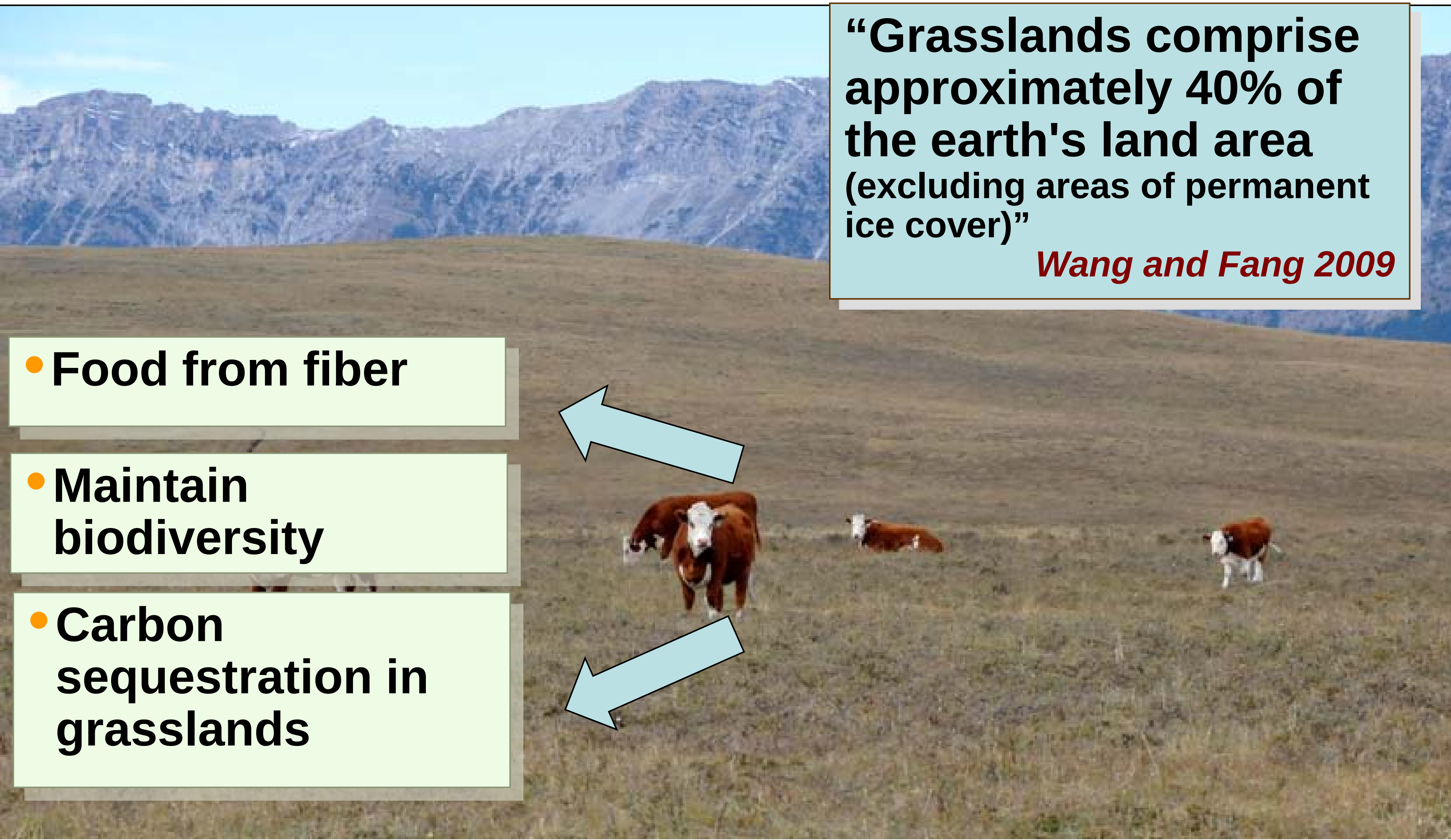
- **Food**
- **Fuel**
- **Nutrient cycling**
- **Livelihood**
- **Habitat**
- **‘Wild places’**
- **Water/air filtering**
- **Aesthetics**
- **Draught**
- **Etc…**

Ruminant Livestock:
Stressors or benefactors?

Facet	Detrimental	Favorable
Greenhouse gases	Source of CH_4, N_2O	Grassland C sink
Food	Compete for grain	Food from inedible grass
Nutrients	Pollutant source	Recycling agent
Biodiversity	Land use change	Grassland preservation
Social aspects	Nuisance	Aesthetic appeal

From H. Janzen, GGAA2010

Connecting Livestock to their Habitat



"Grasslands comprise approximately 40% of the earth's land area (excluding areas of permanent ice cover)"
Wang and Fang 2009

- **Food from fiber**
- **Maintain biodiversity**
- **Carbon sequestration in grasslands**

Take Home Message

- Agriculture is responsible for 8 – 12% of GHG emissions
- Regionally, livestock emissions broadly related to numbers and production practices
- Population growth will drive up GHGs from agriculture
- Need to consider efficiency
- Need to look beyond GHGs (otherwise we can make the wrong decisions in terms of our grasslands)

Take Home Message

- Need integrated teams (livestock, crop, soils, measurement, ecologists, economists, etc) to make a difference
- Need to involve developing countries
- Need local data - solutions are place dependant
- Better use of models to integrate the information and allow testing of “what-if scenarios”


Questions?
237