# Data & inventories relevant for LCA of organic agriculture & food systems

Adrian Williams,
Eric Audsley
Natural Resources Management Centre
Laurence Smith, Organic Research Centre

Cranfield UNIVERSITY

- What is wanted in agricultural LCA?
- Where/how to get it?
- Systems approach
- Differences?
- Needs for the future.

# What is wanted in agricultural LCA?

## Basic data needs

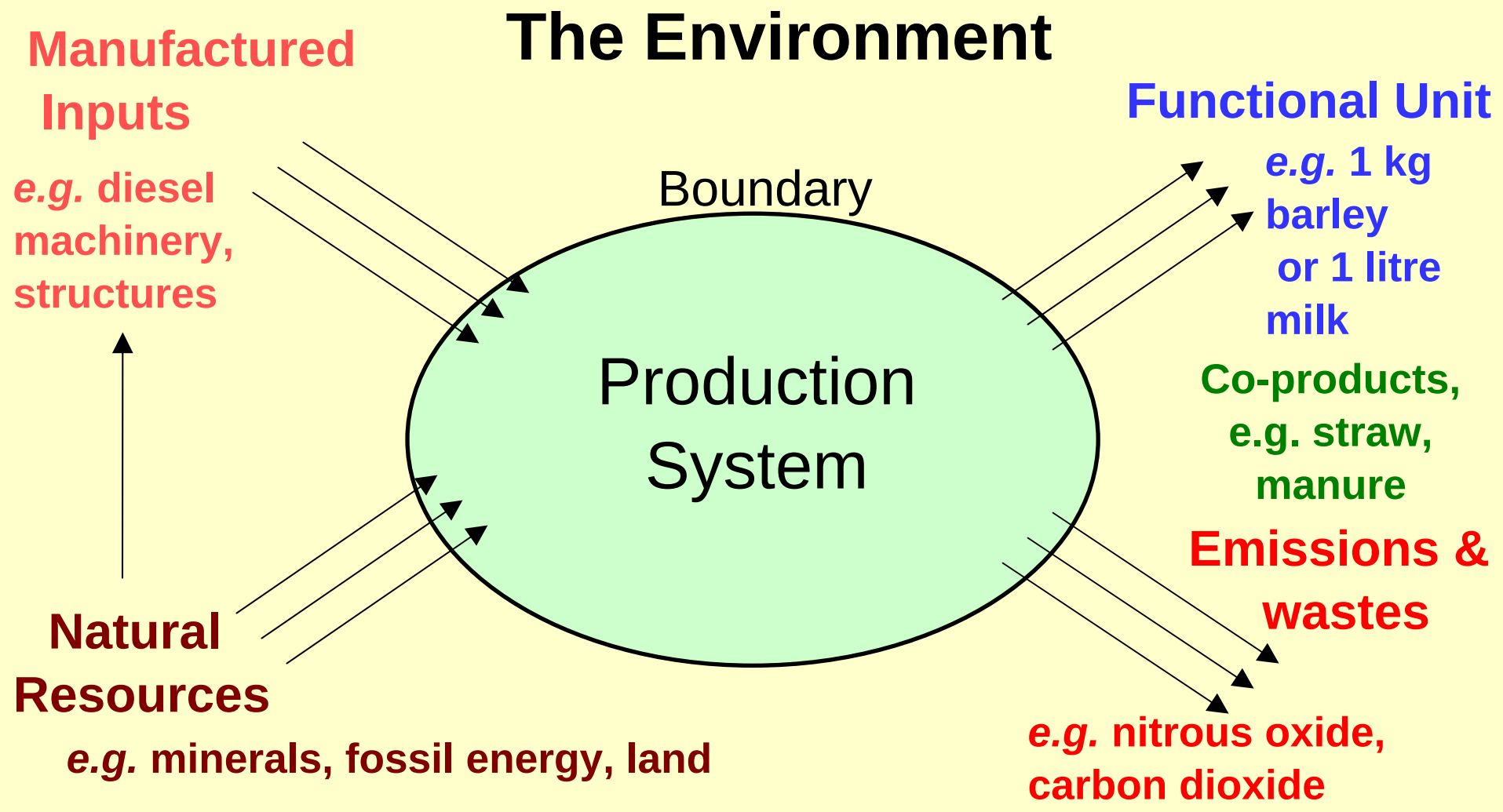
- Inputs (including activities)
- Processes
- Outputs

- Hence:
- Useful products + Emissions + Resource Use

- **What more?**

# LCA Outline

**Inputs = Outputs**
**Mass flows measured at the system boundary must balance.**

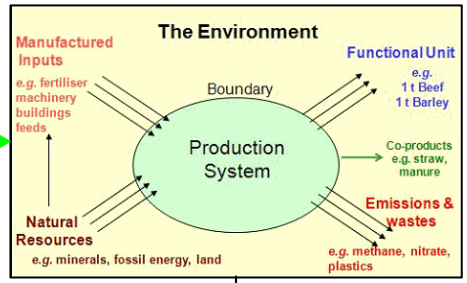


# Cradle to grave is fullest application of LCA

(We stop at LCIA)

Cranfield UNIVERSITY

## Production




Processing

Distribution

Consumption / use

Disposal

Each step has its own set of inputs and outputs like production

Recycling options at most stages

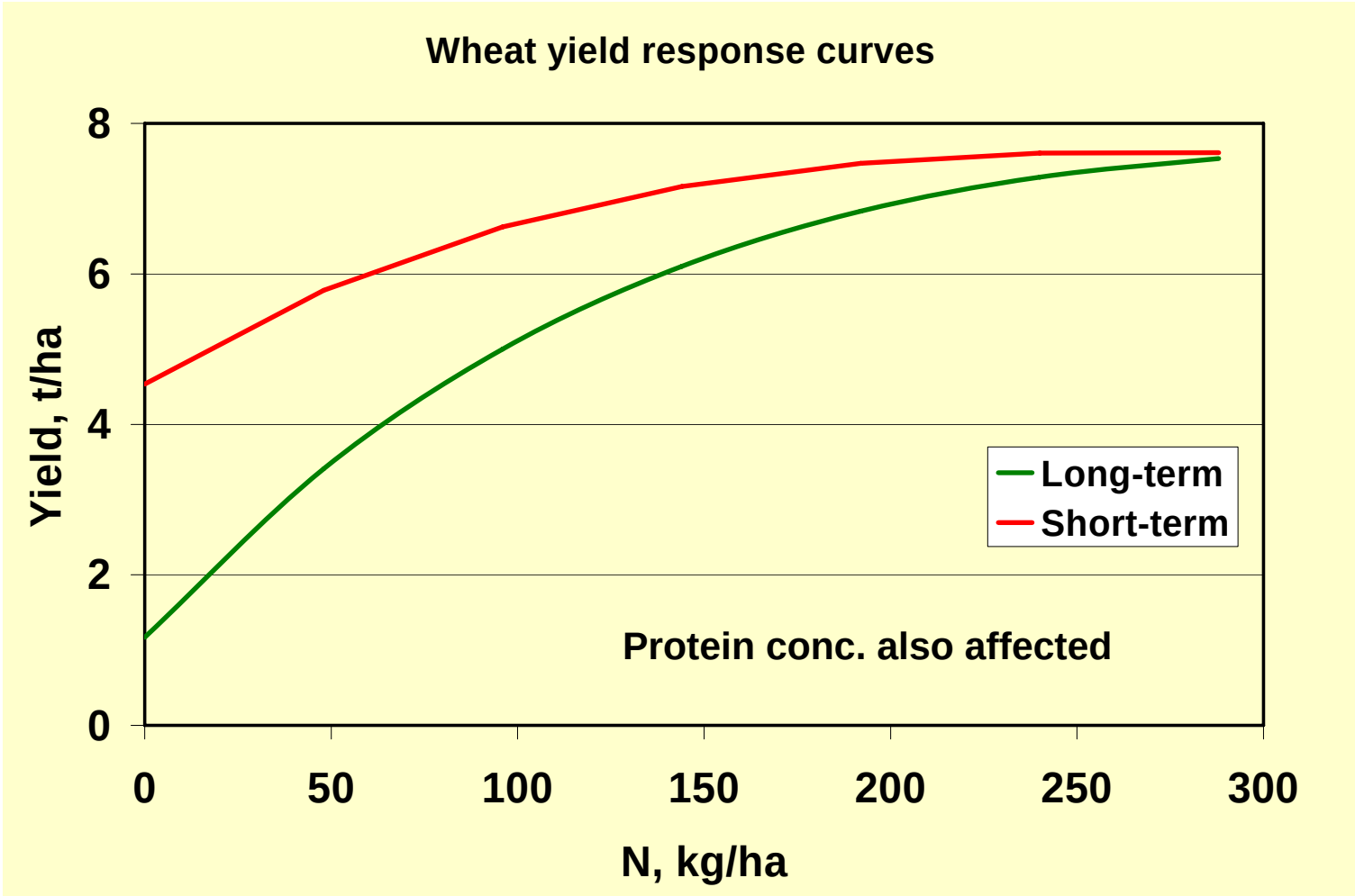
Systems Modelling convergence

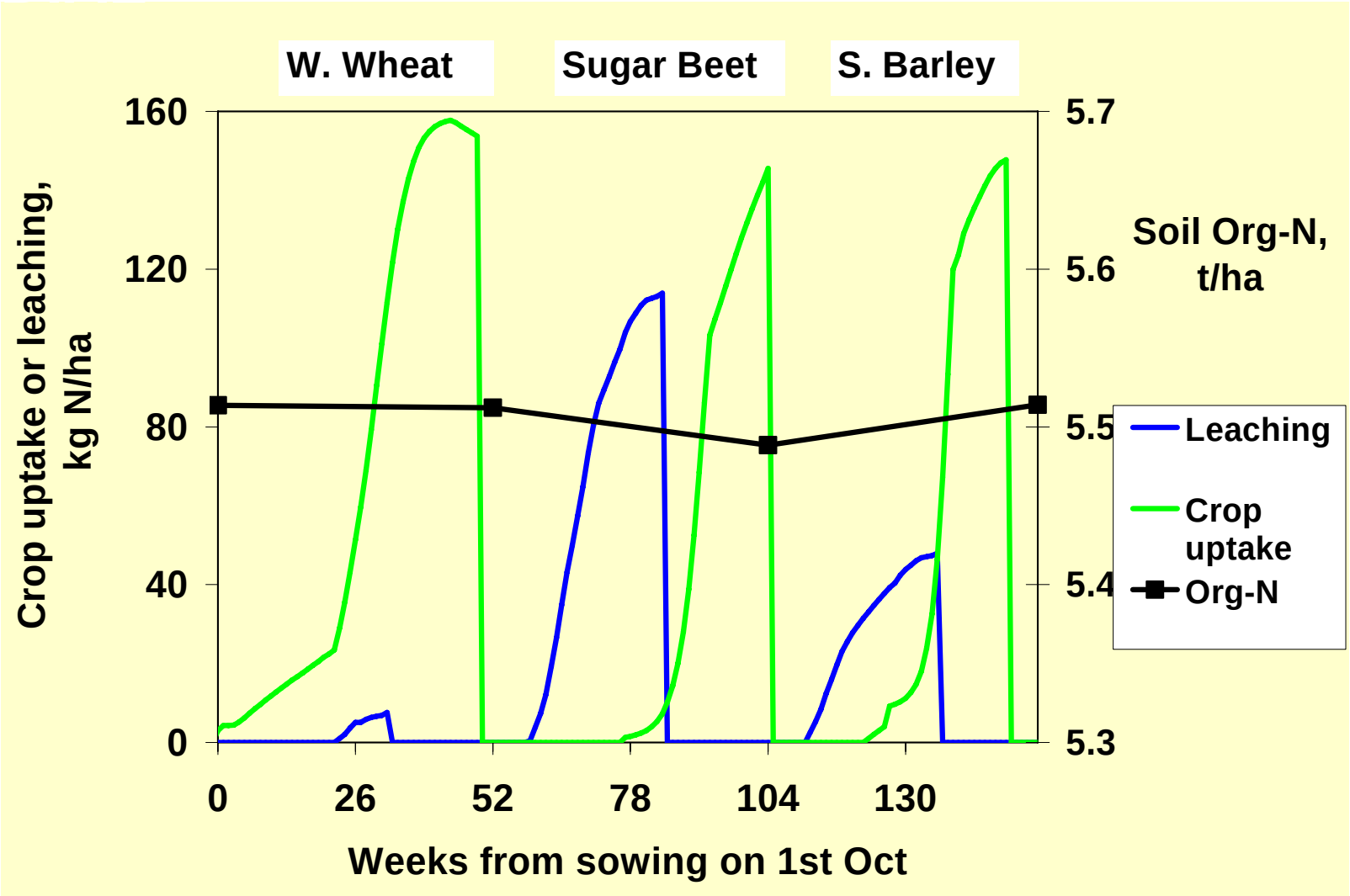
# What more indeed?

## What org and non-org differences?

- All agri-environmental science should be in common
- Purpose & timescale
- Short term illusions or long term (t.) sustainability?
- Yield data central (crops then animals)
- Long term N supply (enabling)
- N pool maintenance
- Long term N balance (emissions)
- Leaching and denitrification
- Soil & biomass C
- Weed control
- Cultivations or chemicals

# Wheat yield and N supply




W. Wheat
Sugar Beet
S. Barley
160
120
80
40
0
5.7
5.6
5.5
5.4
5.3
Crop uptake or leaching, kg N/ha
Soil Org-N, t/ha
Leaching
Crop uptake
Org-N
0
26
52
78
104
130
Weeks from sowing on 1st Oct

# What more indeed?

## What org and non-org differences?

- All agri-environmental science should be in common
- Purpose & timescale
- Short term illusions or long term (t.) sustainability?
- Yield data central (crops then animals)
- Long term N supply (enabling)
- N pool maintenance
- Long term N balance (emissions)
- Leaching and denitrification
- Soil & biomass C
- Weed & pest control
- Allocation data

# N cycles and flows (simplified)

- **Atmospheric deposition**
- **Free living fixers** }
- **Legume fixation** }

Plant energy

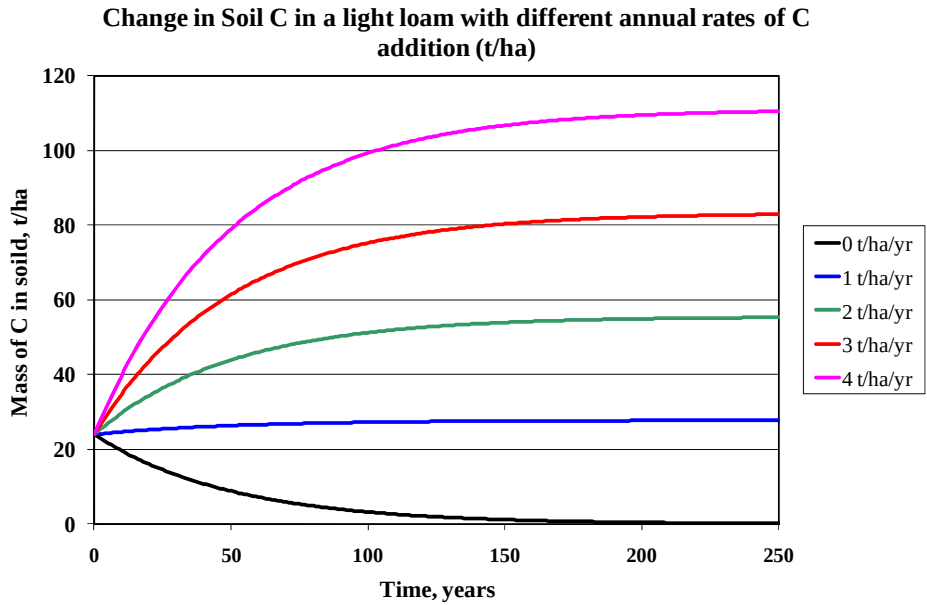
- Imports of manure, compost(ables)
- Chemical fixation (non-org only)
- N for crops in rotations
  - Stockless – (sacrificial) legume
    - Tree and bush fruit
  - Grazing – manure transfer from clover
  - White meat – feed import and export manure
  - Local imbalances
  - Transitions

# Weeds, pests etc

- Long term yields
- Minimal normal rotational cultivation
  - Mechanical & chemical + thermal
- + prevention of build up (e.g. black grass)
  - Mechanical & chemical + thermal
- Failed crops
  - non-germination to sub-standard quality
- Cordon-sanitaire effects

# C balance

- Arable down
- vs. grass up (until equilibrium)




- Imports of manure & compost(-ables) – balance between systems and opportunity costs
- Imports of feeds, hence manure

- Residue and primary crop yield ratios
- Systematic differences?
- IPCC defaults - 2006 (not UK!)

# Animal production

- Productivity coefficients
  - FCR, fecundity, longevity etc
- Feed requirements (energy, protein)
- Manure outputs: quantity and nutrients
- Manure credits & debits (realisation)
- Interdependencies,
  - e.g. hill, upland & lowland sheep
- Direct energy & water
- Veterinary and disinfection

# e.g. Cow feeding model

- Dry matter intake =

  $f_d$ {Cow Weight, Milk Yield*, Concentrates}
- Energy required =

  $f_e$ {Cow weight, Milk Yield, Pregnancy}
- Protein required =

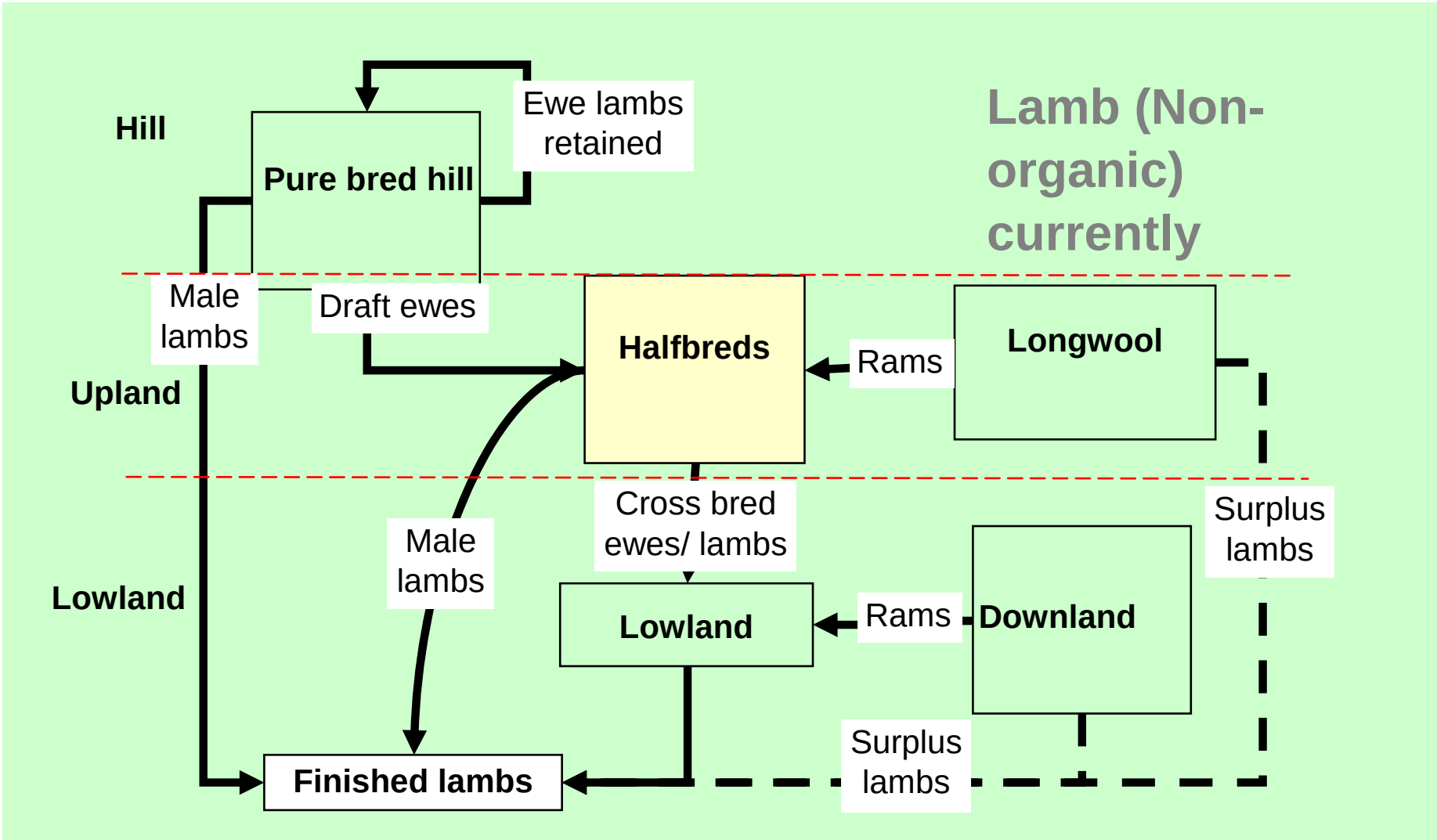
  $f_p$ {Cow weight, Milk Yield, Pregnancy}

  * Includes volume and composition
- Solve for amount of forage and concentrates required
- Manure balanced

# Animal production

- Productivity coefficients
  - FCR, fecundity, longevity etc
- Feed requirements (energy, protein)
- Manure outputs: quantity and nutrients
- Manure credits & debits (realisation)
- Interdependencies,
  - e.g. hill, upland & lowland sheep
- Direct energy & water
- Veterinary and disinfection

# Industry Structure Model (simplified)



# Animal production

- Productivity coefficients
  - FCR, fecundity, longevity etc
- Feed requirements (energy, protein)
- Manure outputs: quantity and nutrients
- Manure credits & debits (realisation)
- Interdependencies,
  - e.g. hill, upland & lowland sheep
- Direct energy & water
- Veterinary and disinfection products

# Diffuse emissions +

- Emission factors
  - Usual IPCC Tiers
  - Legume fixation – 2001 to 2006
    - Double to single hit! Truth?
- Systematically different, uncertainties?
- Leaching from arable, arable-ley, grass only
- Ammonia
- Phosphate
- Pesticide transfer

- Abiotic resource use

# Approaches

- Analyse systems
- Quantify parts and interactions
- Take systems apart
- Take processes apart
- Rebuild them in models
- Test models
- Apply them

# What is really different? (1)

- N by biological fixation (plant energy & $N_2O$)
- N fixation by Bosch-Haber – much non-renewable energy and $N_2O$ (1 + a) *
- N & $CH_4$ related emission factors?
  - None: as long as crop-animal mass balances applied properly.
  - E.g. less N in, so less N out and less offtake.
- Leaching-offtake interactions by grass-legumes (& animals)
  - No reason for difference, but much more important in organic

# What is different? (2)

- Soil-biomass C?
  - Biomass transient
  - Soil C – processes the same, but balance may differ (>1 location for livestock)
  - Big Q: when does grass soil C reach equilibrium across soil-climate-management types at different depths?
  - Uncertainty high
  - Grazing livestock saviour or a one way process?

# Where to get data and answers?

- All agri-environmental science should be in common
- Activity data should be of common quality, but..?
  - Industry (after scrutiny)
- LCA data bases cover many, but may lack particular items, e.g. veterinary medicines, Cu based fungicides
- Basic scientific literature & theory
- Commercial & public datasets
- E.g. *Ecoinvent*, www.agrilca.org, www.foodlca.dk
- LUC factors, e.g. PAS2050, but arbitrary

# Needs for the future

- Research into $N_2O$, $NO_3^-$ & offtake from legumes (grass-clover)
- Organic (i.e. high SOC) soils and IPCC $N_2O$
- Soil C (arable – grass)
- Less usual breeds of livestock
- **Tier 2-3 GHG inventories**
- **Tested** soil-crop simulation C-N models for **all** locations

# Needs (2)

- Activity data (rotations, cultivations, weed control, pest control)
- "domestic" and "overseas" – global market – how exactly are Kazakh wheat and Chinese soy grown?
- Co-product allocation –
  - economic values (crop-straw, egg-hen etc)
- Other indicators 
- Consequences of low yields
  - If demand increasing, who is responsible for LUC?

Many thanks for funding from Defra

# Thank you

Fritillary Sunday, Ducklington, Oxfordshire