The future of agricultural modelling *opportunities and dangers*

Nicholas Hutchings

UNIVERSITY OF AARHUS

Dept. of Agroecology

Structure

- Role of modelling
- Opportunities in the future
- Dangers associated with modelling projects

Dynamic modelling can have many roles

- **To test if our understanding of complex systems is adequate**

Test our understanding

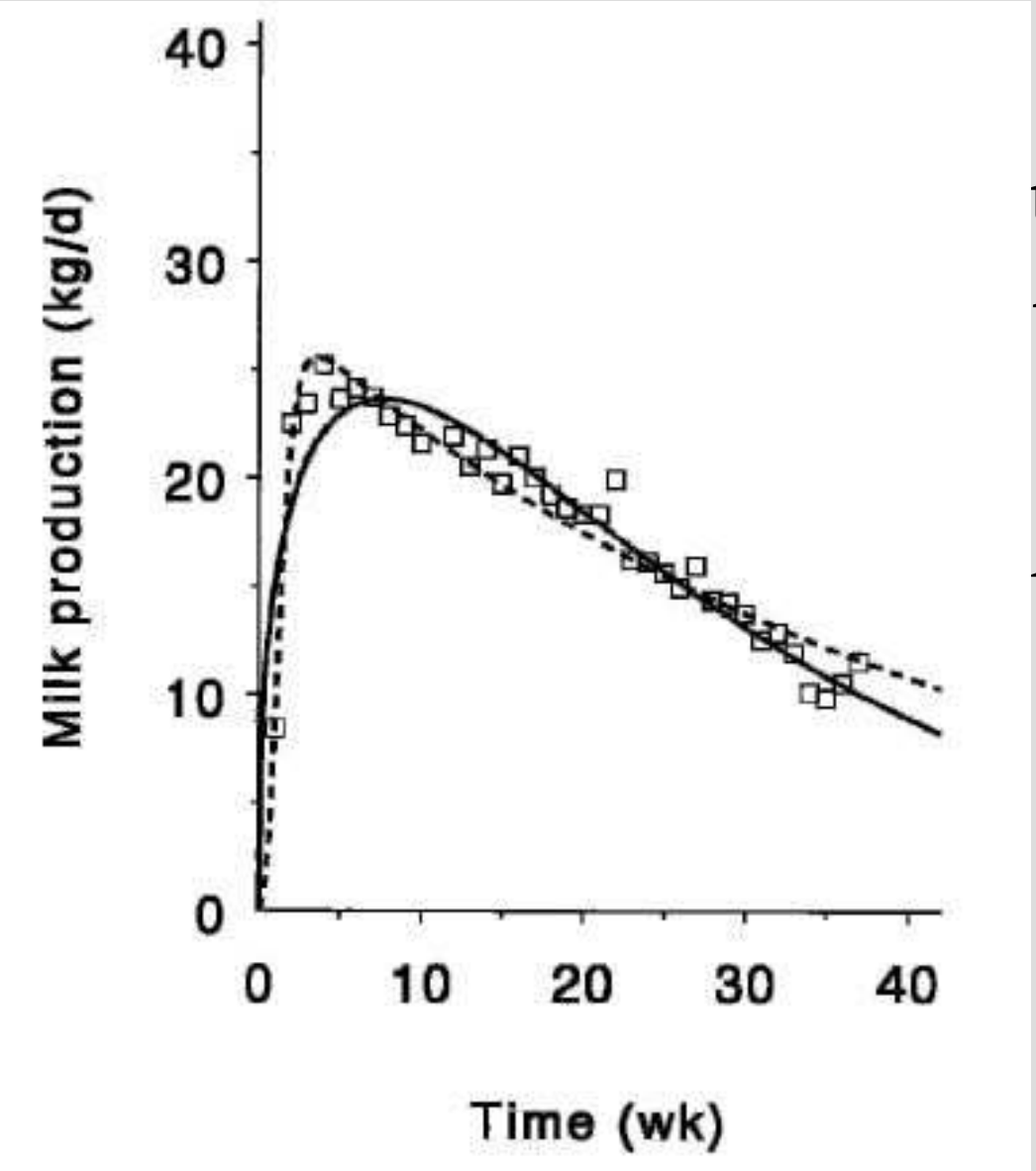
- **Capture the essence of our understanding of a complex process or system**
- **Compare this understanding with empirical observations**
- **Identify what the model can and cannot represent**
- **Response:**
  - More empirical studies – improved understanding
  - Improved description (better use of existing knowledge)

Knowledge synthesis

- **Mechan** **tle***
- **Repres** **th**

$$\frac{dY}{dt} = M \qquad t)).\exp(-c.t)$$

$$\mu=\mu_0.\exp$$



*Dijkstra et al (1997), J Dairy Sci 80:2340–2354

Dynamic modelling can have many roles

- To test if our understanding of complex systems is adequate
- To transfer knowledge to others

Knowledge transfer

- **Enable others (e.g. farmers, advisors) to use the knowledge more easily**
- **Focus on usability and reliability**
- **Reduce demand for input data to a minimum**
- **Retrieve data automatically**
- **User interface**
  - Data input
  - Presentation of results

Pl@nteInfo

LOGIN KONTAKT FORETRUKNE PRINT

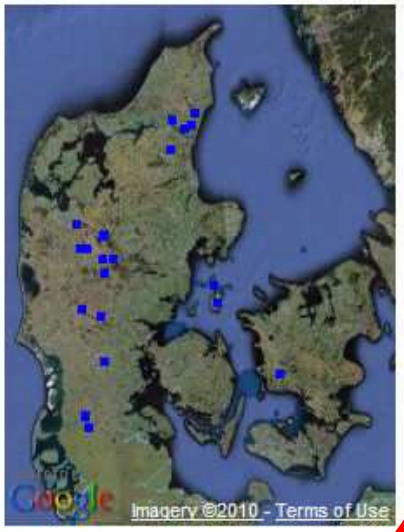
9. august 2010

Gæst

Forside | Vejret | Afgrøder | Planteværn | Vand | Jord | Kvælstof | Sorter | Bier | Links | Hjælp | Statistik | English

Potato Late Blight

Monitoring



B recordings last 10 days
LB recordings older than 10 days
Mere information om skimmelfund

News from the field

Første skimmel registreret på Samø

Første fund af kartoffelskimmel i Danmark er sket på Samsø og i Nordjylland 8. Juni. Fundet på Samsø er gjort i en mark med anstrengt sædskifte men uden nogen form for plast- eller fiberdække. I Nordjylland er fundene sket i form af små primær smittede planter på 8-10 cm. Spredningen på Samsø kan meget vel være sket fra en meget tidlig forekomst af jordsmitte eller fra spisekartofler, som har været fremspiret under plast eller fiberdække. I Nordjylland optræder smitten som primær smitte, som kommer enten i form af jordsmitte eller meget tidlig knoldsmitte. Kilde: Lars Bødker

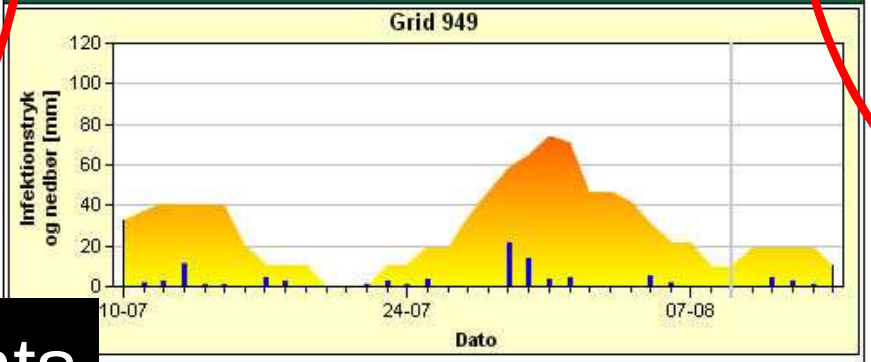
mindre tekst

Opdateret 09-06-2010 08:16:00 af Jens GrÅ¸nbech Hansen

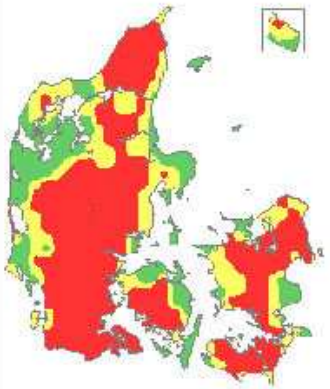
Skimmel i Sydsverige

Der er fundet skimmel i Sydsverige på halvøen Bjäre, hvor man dyrker tidlige kar mere tekst

Infection Pressure



Blight Weather 9/8



High risk	+10 hours with RH ≥88% and Temp ≥10°C
Possible risk	+10 hours with RH ≥86% and Temp ≥10°C
Low risk	

Dagens skimmelvejr i Danmark de seneste 25 dage
Dagens nedbør i Danmark de seneste 25 dage
Infektionstryk ved forsøg

Measurements

Skimmelforsøg, AU, 2005
Skimmelforsøg, AU, 2004
Skimmelforsøg, AU, 2003

Cultivars and resistance

Sorter og skimmelresistens
Skimmelresistens fra Eucablight-forsøg

New Knowledge

Info og artikler fra LC
Euroblight workshop Arras, 2010 - læs indlæg
GILB konference, 2008 - læs indlæg

Forecast

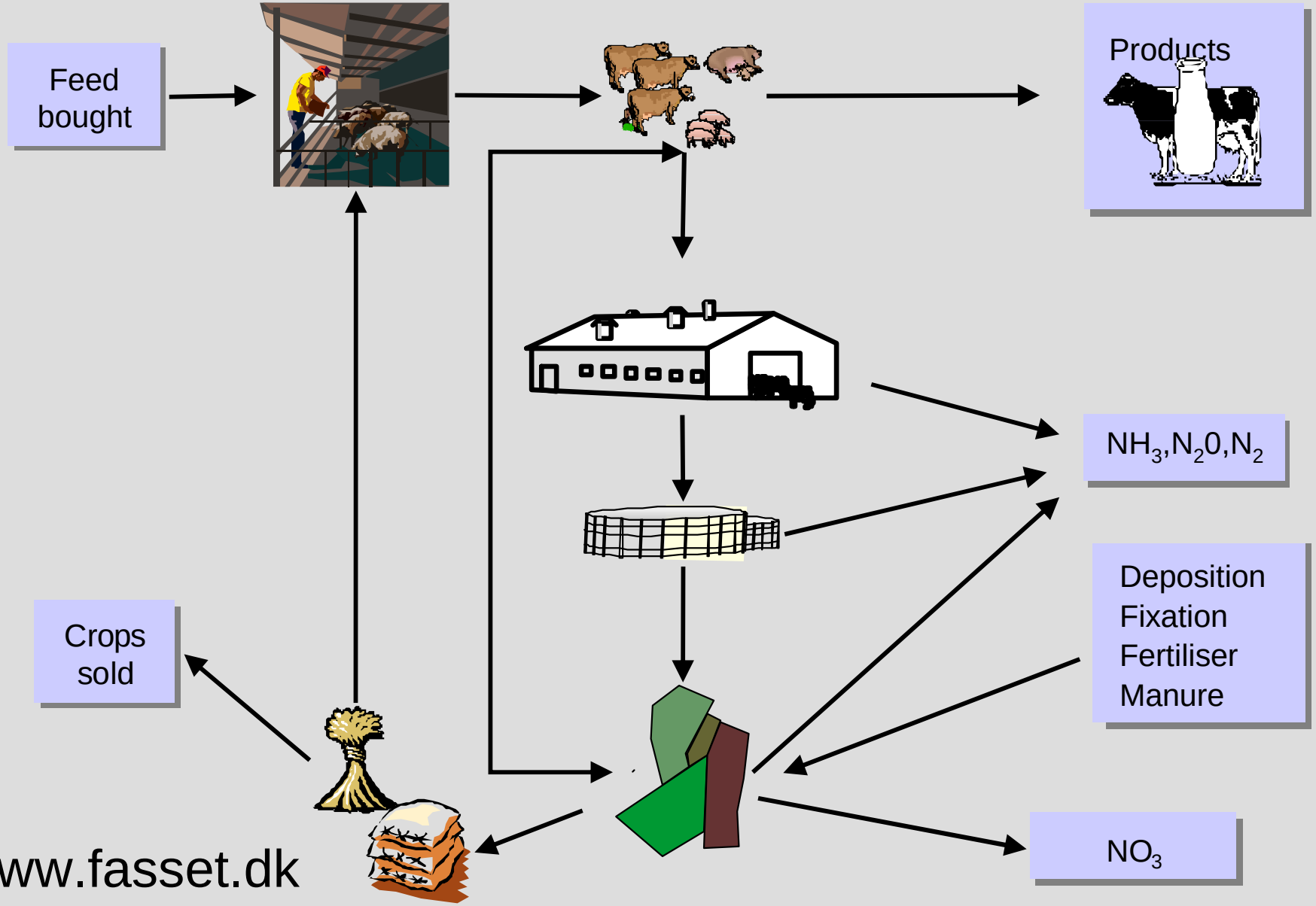
- North Jutland
- Mid- og West Jutland
- East Jutland
- South Jutland
- Funen
- West- and South Sealand and Lolland Falster
- Copenhagen and North Sealand
- Bornholm

Modelled risk

Dynamic modelling can have many roles

- **To synthesis our understanding of complex systems**
- **To transfer knowledge to others**
- **To link knowledge from different disciplines – systems modelling**
  - Greater need on livestock farms than arable farms

Linking disciplines



www.fasset.dk

Linking disciplines:
N cycling on Danish pig farm

	Pig farm
	kg N ha^{-1} yr^{-1}
Fertiliser	47
Seed	3
Atmosphere	15
Animal feed	275
Total imported	*339*
Crop products exported	91
Animal growth	104
Total exported	*195*
N surplus	**144**

	Pig farm
	kg N ha^{-1} yr^{-1}
Fertiliser	47
Seed	3
Atmosphere	15
Animal feed	275
Total imported	*339*
Crop products exported	91
Animal growth	104
Total exported	*195*
N surplus	**144**
NH_3 housing	27
NH_3 manure storage	4
NH_3 field - mineral	1
NH_3 field - manure	25
N_2 +N_2O soil	7
NO_3 leaching	76
Change in soil	5

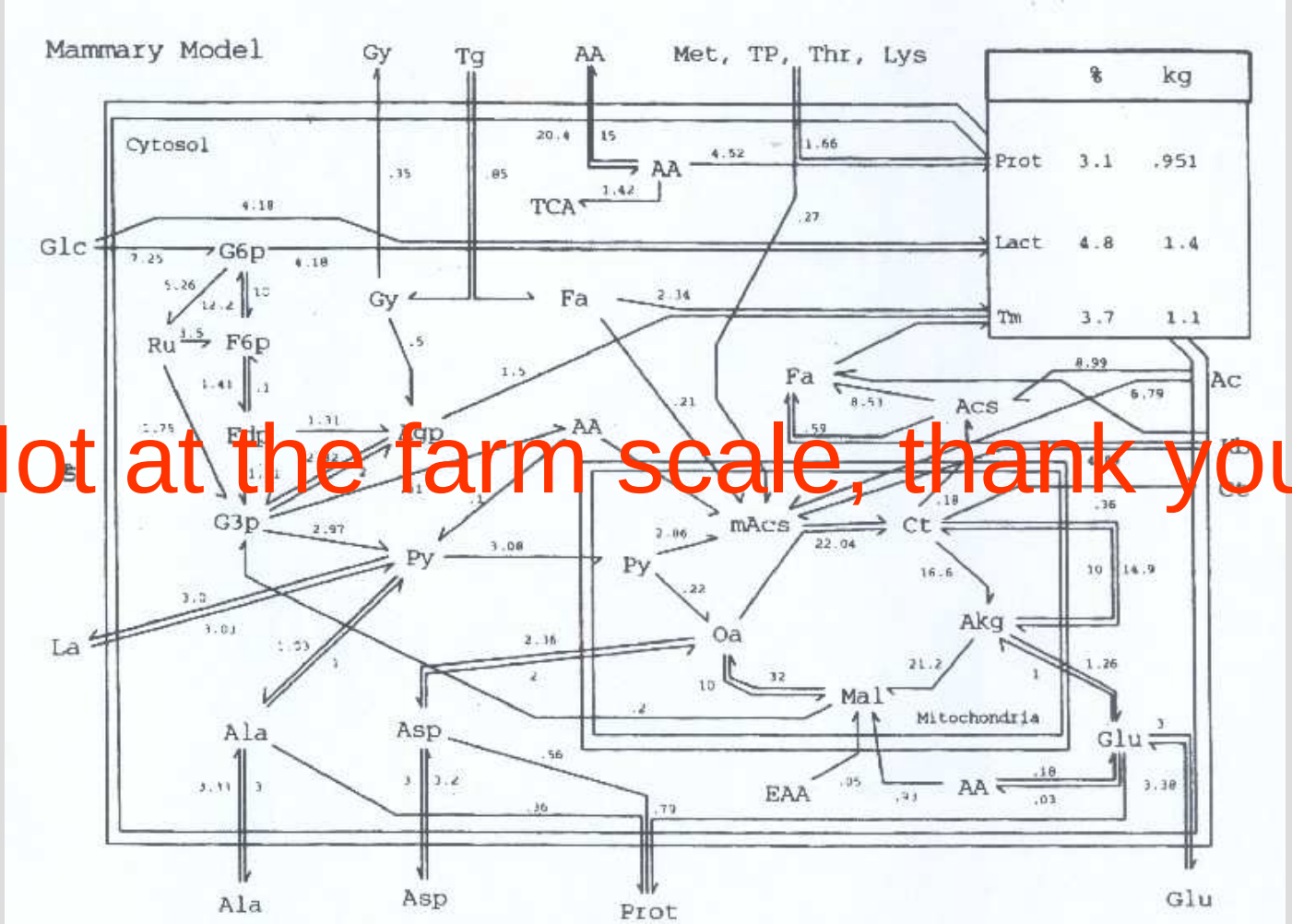
	Pig farm	Pig abated
	kg N ha^{-1} yr^{-1}	
Fertiliser	47	47
Seed	3	3
Atmosphere	15	15
Animal feed	275	275
Total imported	*339*	*339*
Crop products exported	91	105
Animal growth	104	104
Total exported	*195*	*209*
N surplus	**144**	**131**
NH_3 housing	27	14
NH_3 manure storage	4	5
NH_3 field - mineral	1	1
NH_3 field - manure	25	8
N_2 +N_2O soil	7	9
NO_3 leaching	76	86
Change in soil	5	8

	Pig farm	Pig abated	Pig abated & adjusted
	kg N ha^{-1} yr^{-1}		
Fertiliser	47	47	37
Seed	3	3	3
Atmosphere	15	15	15
Animal feed	275	275	275
Total imported	*339*	*339*	*329*
Crop products exported	91	105	97
Animal growth	104	104	104
Total exported	*195*	*209*	*202*
N surplus	**144**	**131**	**127**
NH_3 housing	27	14	14
NH_3 manure storage	4	5	5
NH_3 field - mineral	1	1	1
NH_3 field - manure	25	8	8
N_2 +N_2O soil	7	9	9
NO_3 leaching	76	86	83
Change in soil	5	8	8

Linking disciplines

- **Benefits:**
  - Gain a holistic understanding of system function
  - Account for interactions between components of a system
- **Costs:**
  - Often requires adaptation/simplification of models
  - Requires exchange of information between models

Simulating lactation – complex model

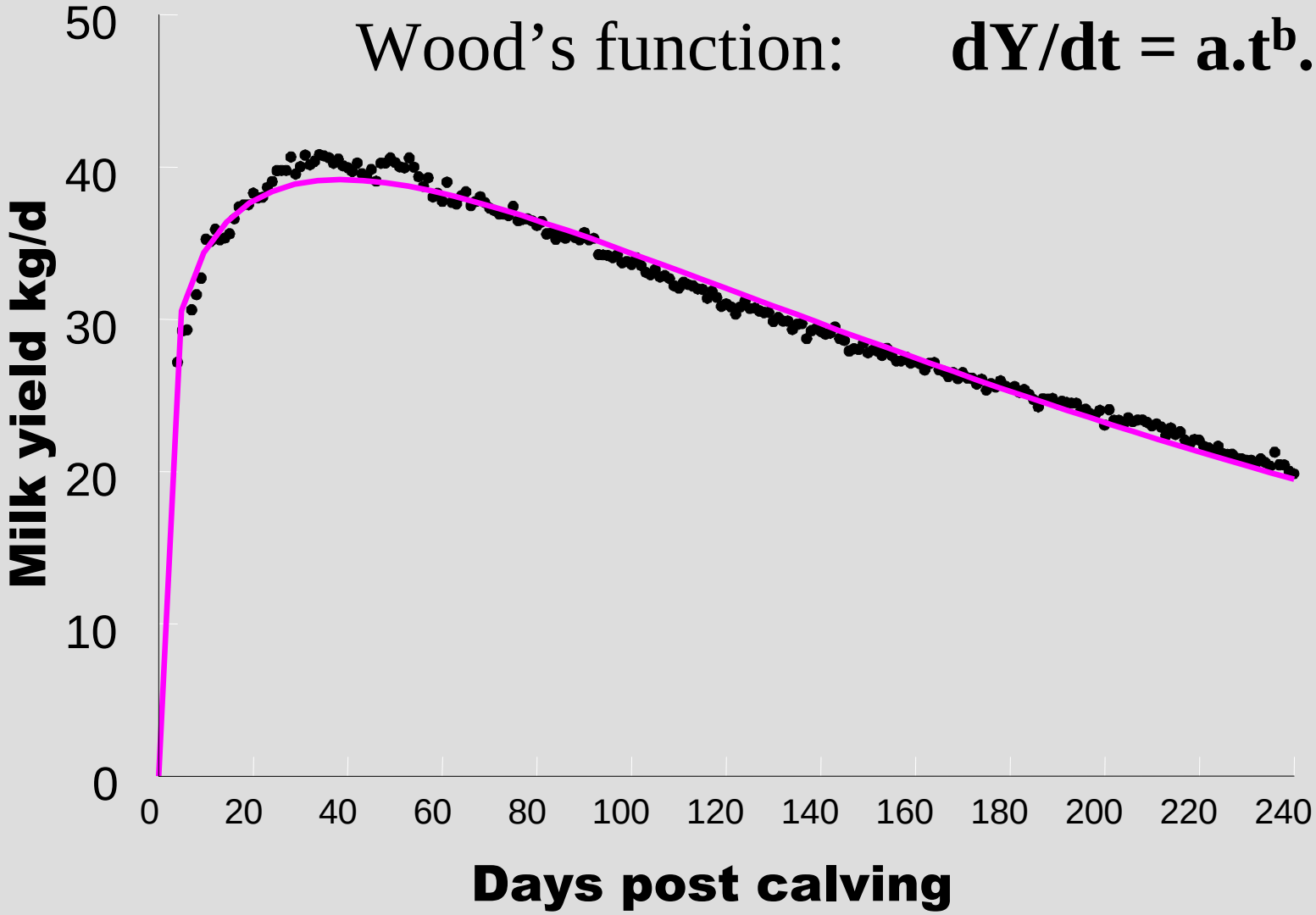


Not at the farm scale, thank you

Figure 4. Block diagram for a model of cow mammary gland metabolism. Codes and abbreviations: blood glucose (BGLUCOSE), glucose-6-phosphate (G6P), ribulose-5-phosphate (Ru5P), fructose-6-phosphate (F6P), fructose-1,6-bisphophate (F16BP), glyceraldehyde-3-phosphate plus dihydroxyacetone-phosphate (G3P), pyruvate (PYR), blood lactate (BLAC), acetyl-CoA (Ac-CoA), citrate (CIT), α-ketoglutarate (KG), malate (MAL) oxaloacetate (OAA), fatty acyl-CoA (FA-CoA), blood acetate (BACET), glycerol (GLY), α-glycerol phosphate (GP), triacylglycerol (TAG), α-glycerol-P (AGP), mitochondrial acetyl-CoA (mAcs), citrate (Ct), methionine (Met), phenylalanine plus tyrosine (TP), threonine (Thr), lysine (Lys), lactose (LACT), and milk fat (Tm).

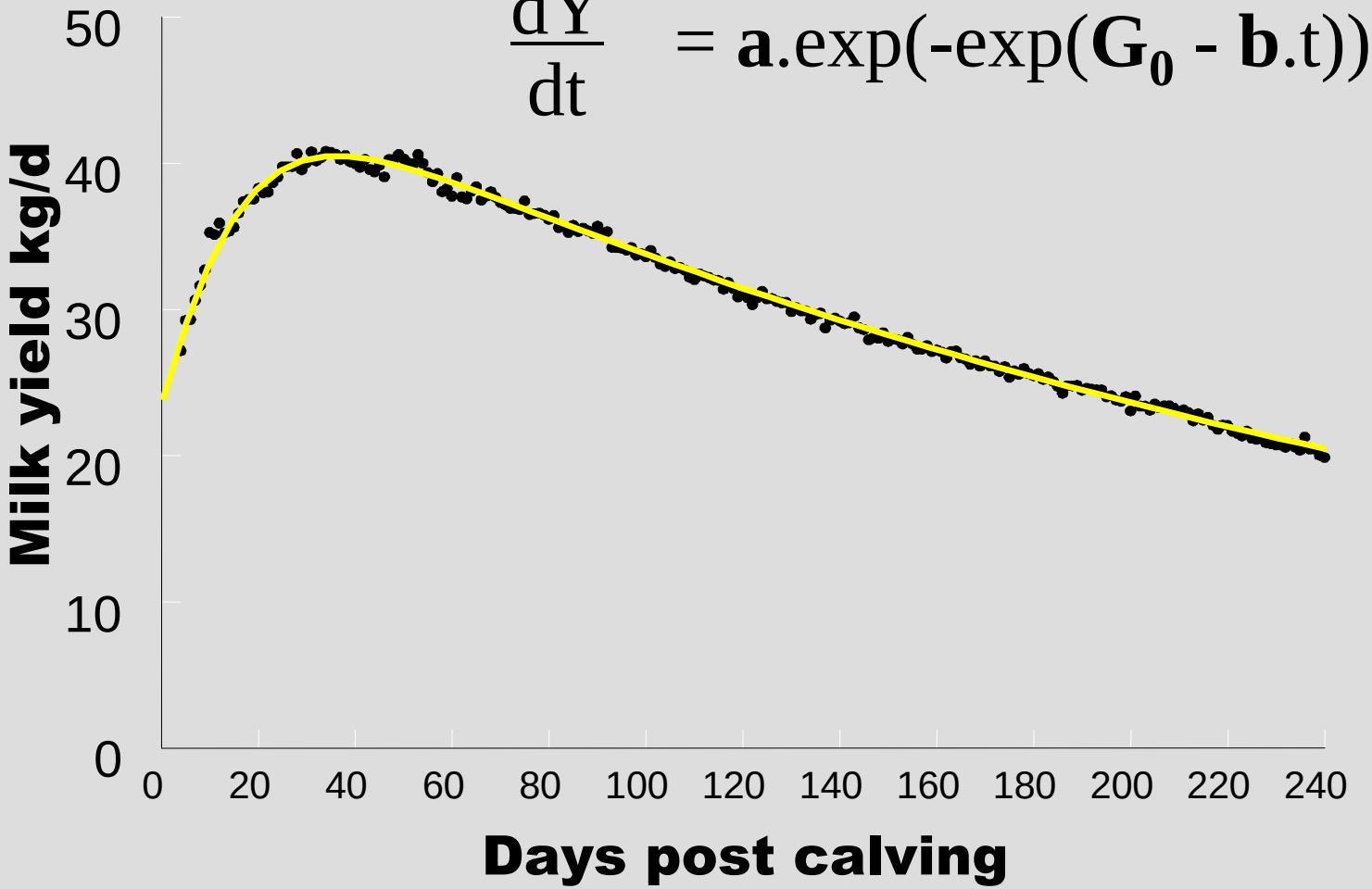
Simulating lactation – simple model

Wood's function: $dY/dt = a.t^{b}.exp(-ct)$



Alternative solution

$$\frac{dY}{dt} = \mathbf{a}.\exp(-\exp(\mathbf{G_0} - \mathbf{b}.t)).\exp(-\mathbf{c}.t)$$



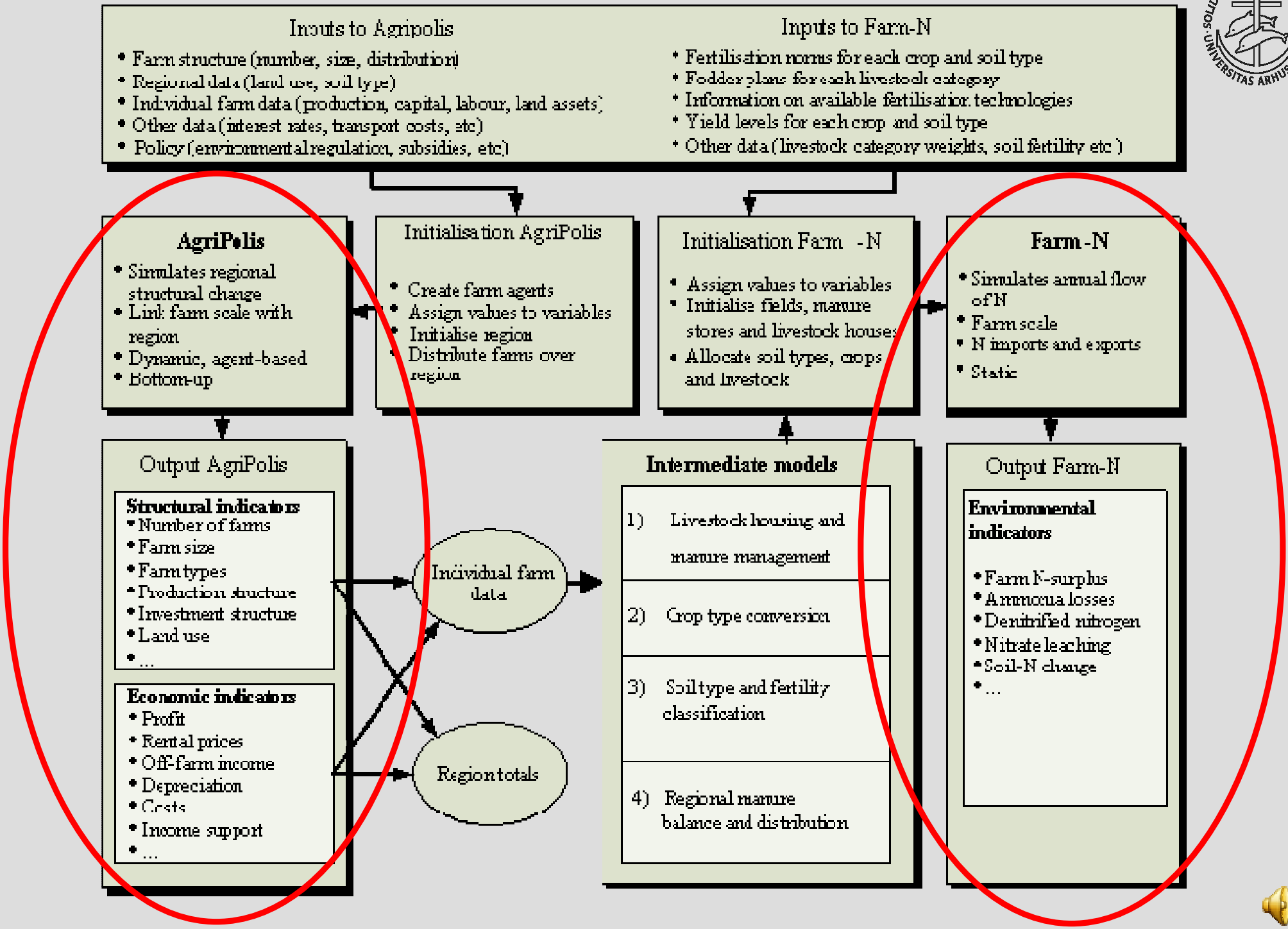
Emmans, G.C., Fisher, C., 1986. Problems in nutritional theory. In: Fisher, C., Boorman, K.N. (Eds.), Nutrient Requirements of Poultry and Nutritional Research, Butterworths, London, pp. 9–39.

Alternative solution

- **More complex than Wood's equation**
  - Additional parameter
- **More work to parameterise for a single lactation**
- **Less work to parameterise for multiple lactations**
  - $\mathbf{G_0}$ and **b** are constants across lactations
- **Greater biological meaning**

Cost of linking models

- **Objective: to investigate the effect of structural change in agriculture on losses of nitrogen to the environment**
  - Structural change = changing farm size and type in a region
- **Agent-based economic model (AgriPolis)**
- **Farm nitrogen budget model (Farm-N)**


Inputs to Agripolis
• Farm structure (number, size, distribution)
• Regional data (land use, soil type)
• Individual farm data (production, capital, labour, land assets)
• Other data (interest rates, transport costs, etc)
• Policy (environmental regulation, subsidies, etc)
Inputs to Farm-N
• Fertilisation norms for each crop and soil type
• Fodder plans for each livestock category
• Information on available fertilisation technologies
• Yield levels for each crop and soil type
• Other data (livestock category weights, soil fertility etc.)
AgriPolis
• Simulates regional structural change
• Link farm scale with region
• Dynamic, agent-based
• Bottom-up
Initialisation AgriPolis
• Create farm agents
• Assign values to variables
• Initialise region
• Distribute farms over region
Initialisation Farm -N
• Assign values to variables
• Initialise fields, manure stores and livestock houses
• Allocate soil types, crops and livestock
Farm-N
• Simulates annual flow of N
• Farm scale
• N imports and exports
• Static
Output AgriPolis
Structural indicators
• Number of farms
• Farm size
• Farm types
• Production structure
• Investment structure
• Land use
• ...
Economic indicators
• Profit
• Rental prices
• Off-farm income
• Depreciation
• Costs
• Income support
• ...
Individual farm data
Region totals
Intermediate models
1) Livestock housing and manure management
2) Crop type conversion
3) Soil type and fertility classification
4) Regional manure balance and distribution
Output Farm-N
Environmental indicators
• Farm N-surplus
• Ammonia losses
• Denitrified nitrogen
• Nitrate leaching
• Soil-N change
• ...

Opportunities in the future

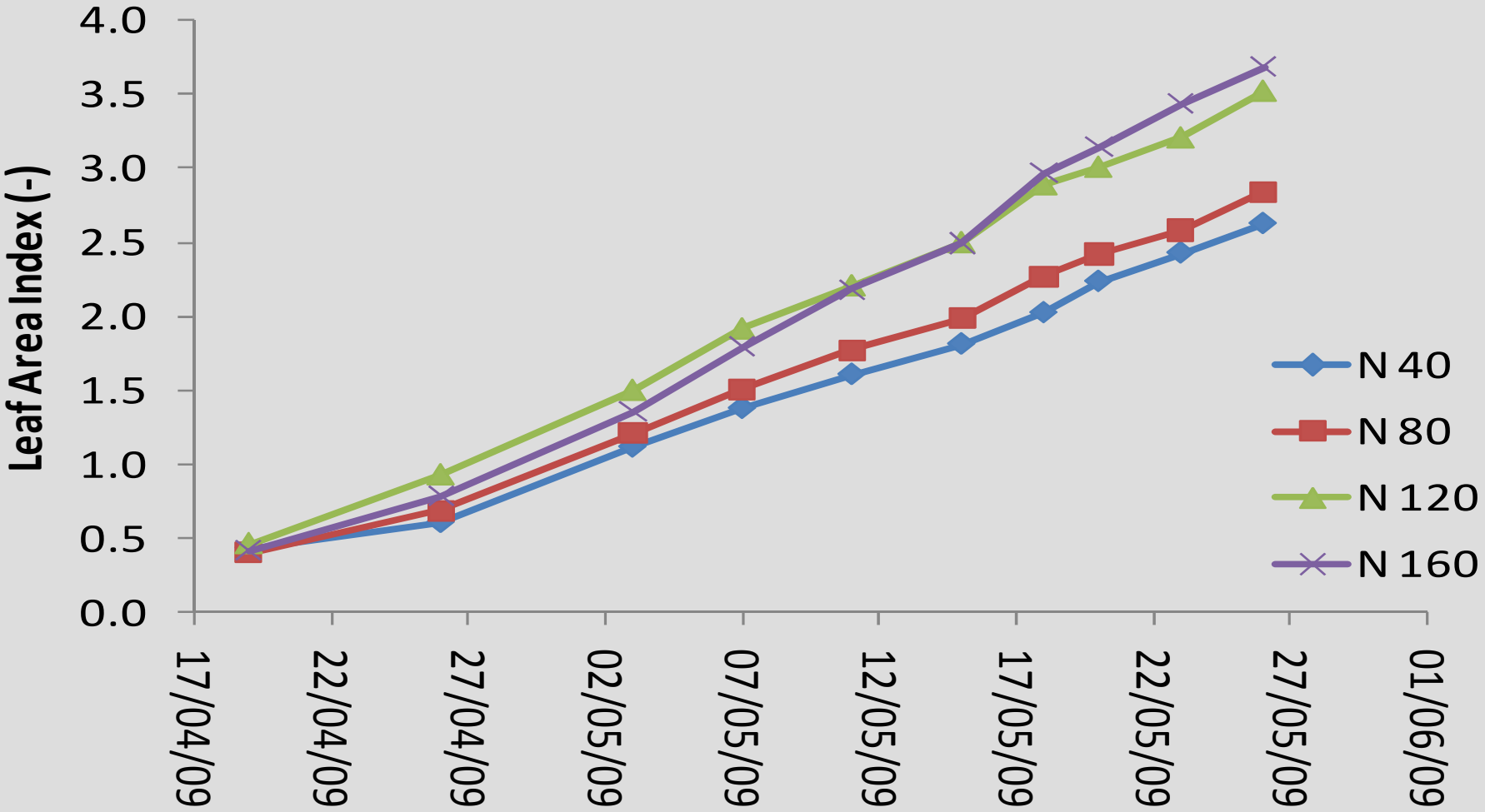
- **All three roles for modelling will remain important**
- **Two examples:**
  - Information and communication technology (ICT)
  - Policy support

Example 1: Information and communications technology (ICT)

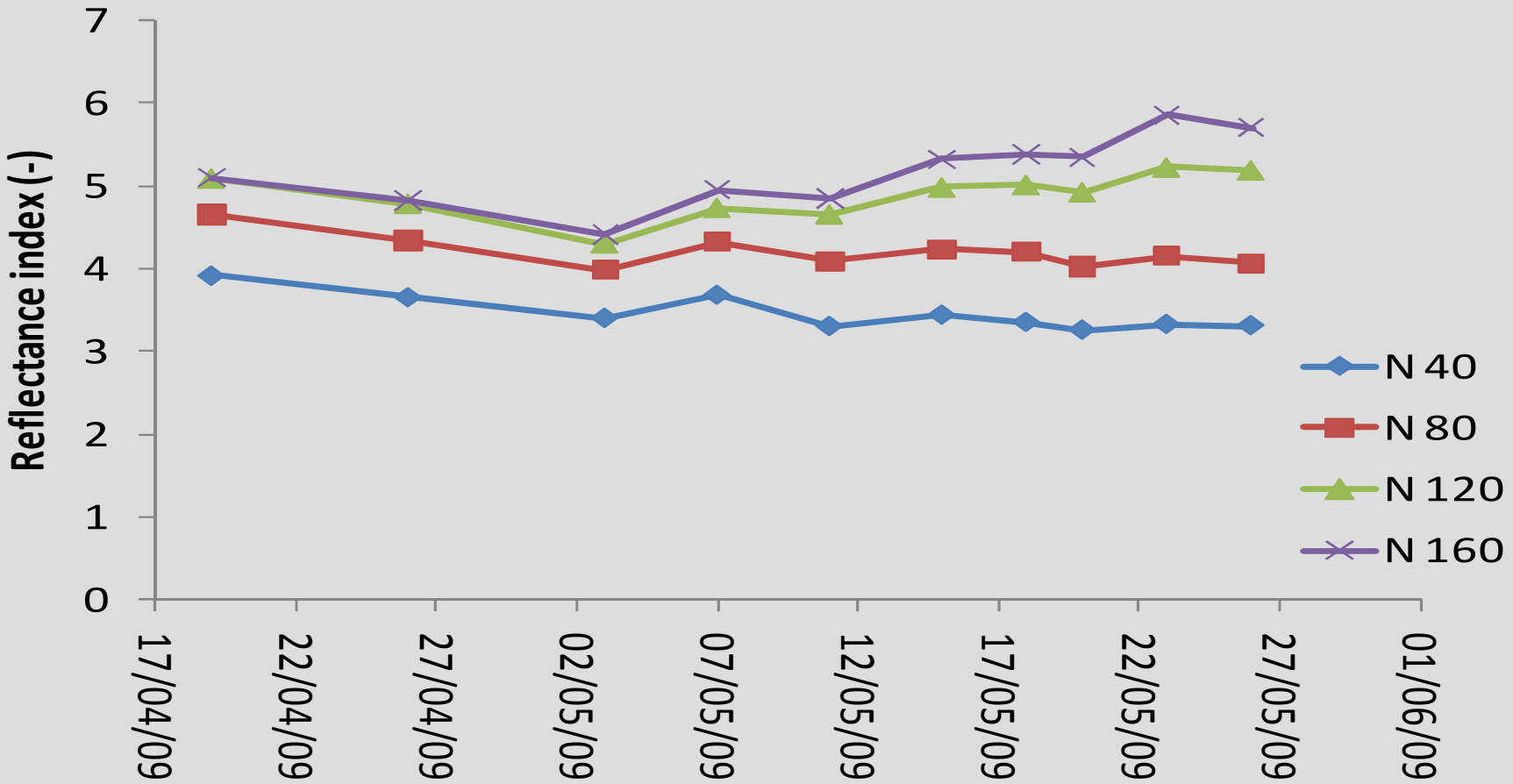
- More, improved and cheaper data from sensors
- Computing power doubles ~ 2 years
- GPS (cheap, accurate)
- 3G mobile phone (4G in 2011-2013)
- Increased global mobile phone coverage
- Increased mobile phone use in developing countries

Laser crop sensor

Laser crop sensor



Laser crop sensor



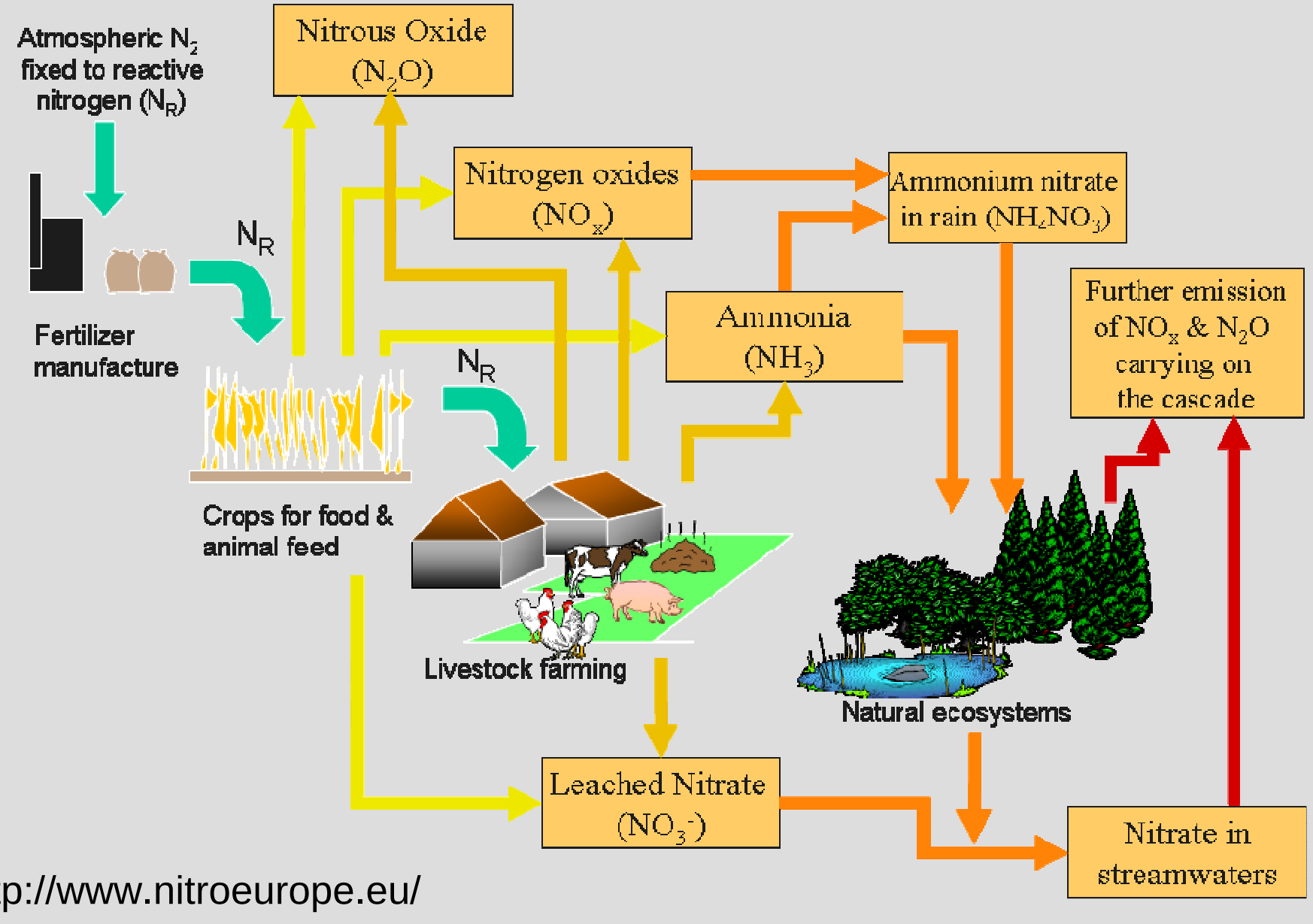
Models and ICT

- **Dynamic models are data-demanding**
- **Sensor technology + fast, mobile communications can increasingly provide these data**
- **Data for testing models**
- **More extensive use of modelling**
  - To interpret measurements
  - To predict consequences of management options

Example 2: Policy support

- **The policy and regulatory environment is becoming more complex**
- **Multiple policies impact on the same agricultural areas**
  - e.g. Water Framework Directive, Habitats Directive, Common Agricultural Policy, Kyoto Agreement
- **Food production, climate change and greenhouse gas emissions are major issues**
- **Policymakers need to gain an overview of the consequences of policy/regulatory measures**

European nitrogen flows



http://www.nitroeurope.eu/

Important policy areas

- **Food production**
- **Greenhouse gas emissions**
- **Nutrient losses to the environment**
- **Diversity and abundance of wild flora and fauna**
- **Socio-economic consequences**
  - For farmers
  - For the wider society
- **Modelling can help identify negative and positive interactions between policy areas**

Dangers in modelling projects

- **Extracts from the most important scientific journal never published**

Projects fail

- **Cultural differences c**
  - to b be
  - olo ew the
    tly
- **Eff r tech t is un**
- **Fai taff r**

Project results are not used efficiently

- **The technical documentation is not written**
- **Model code is not freely accessible**
  - Personal, institutional or commercial protectionism
- **Raw data are not retained**
- **Data are retained but not freely accessible**
  - Protectionism
  - Non-standard format when one is available
  - No standard format available (e.g. livestock feeding, manure management)

What can modellers do?

- **Improve planning and management of modelling projects**
- **Choose software tools carefully**
  - Excel, Modelmaker, MathCad may be adequate
- **Take a longer-term view**
  - Scientific publications are necessary output but not sufficient alone
- **Support/develop/improve standards**
  - Model documentation
  - Data archiving
  - Software for linking models

Conclusions

- Models have a number of valid roles
- Increasingly used by scientists, farmers/advisors and policymakers
- Results of modelling are often used inefficiently
- Greater focus on documentation and openness
- More collaboration and coordination, less competition and duplication