FACCE MACSUR

L1.4-D1: Farm-scale model linkage for ruminant systems

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Abstract/Executive summary

This report describes the findings of the first workshop and associated actions of task L1.4. The findings detailed below, along with the outputs of a second workshop (L1.4-D2) are currently being synthesized into an article for submission as a peer reviewed paper. The work presented here addresses the scientific/conceptual issues related to model linkage.

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Introduction

The task L1.4 deals with modelling the interactions between farm components (livestock, grassland, animal housing, manure storage, farm management). The argument for this task is as follows. Within agriculture, there has been a long history of model building. This has left a legacy of models, most of which have functionality beyond the initial purpose for their development. Nevertheless, many models are not reused, representing an inefficient use of the considerable resources required to develop new models. Models can be reused by linking existing models but this presents both scientific/conceptual and technical challenges. The former arise because different models may vary in their concepts of the same components. In technical terms, model documentation may be inadequate, models may be implemented in different programming languages/environments or there may be legal or property rights barriers. Past attempts to link models within agriculture have been either via bespoke or generic linkage systems. The former have the advantage that they can be closely tailored to a given objective, but involve a considerable cost. Generic linkage systems provide a framework that can potentially reduce the investment necessary to link models. However, using such linkage systems incurs a cost in terms of the time necessary to learn how to use them and may constrain the functionality that can be achieved.

Methods

Task L1.4 was undertaken in two parts, with the first dealing with scientific/conceptual issues and the second dealing with technical issues relating to model linkage. Two workshops have been used to address these issues. Workshop activities have been synthesized after each event, with the goal of producing a peer reviewed paper on the topics covered. This paper represents the outcomes of the first workshop and an associated survey of models.

Ruminant livestock farming both contributes to global climate change and is affected by it. It contributes to global warming through the emission of direct and indirect GHGs (CH4, N2O, NO3-, NH3). It can also contribute to or mitigate global warming through changes in the C sequestered in the soil. We will consider the flows of information between components and the timescale with which we need to model them in order to simulate both the contribution to and effects of global warming. Both physical and management components will be included. A workshop was held on 29th October in Braunschweig, Germany (Table 1) to progress the activities described.

Table 1: Agenda for first task meeting Thurs 29 Oct 2015

Start	End	Topic
08:30	08:45	Introduction
08:45	09:15	Livestock
09:15	09:45	Housing

09:30	10:00	Manure storage
10:00	*10:30*	*Coffee*
10:30	11:00	Feed storage, access roads, hardstandings
11:00	12:00	Fields
12:00	*14:15*	*Lunch & plenary*
14:15	14:45	Tactical farm management
14:45	15:15	Operational farm management
15:15	15:45	Summing up and paper plan

Results

Conceptual issues

The conceptual issues that might hinder the reuse of models are:

- Existing models neglect/under-represent important processes
  - Ruminant livestock systems vary widely (e.g. extensive beef, intensive dairy) and existing models were developed for a different system
- Lack of scientific agreement about processes
  - Especially the detail with which to represent them
- Cultural differences
  - e.g. different feed energy accounting systems

The objective of the session was to agree the key functions of farm components, the exchanges of information between them and the frequency with which this should occur.

Terminology

The farm components are in two different categories:

- Biophysical components:
  - Livestock
  - Fields
  - Animal housing
  - Manure storage
  - Feed storage
- Management components
  - Tactical management (annual – seasonal)
  - Operational management (monthly – daily)

An example of a simple combination of components is shown below. The components are in the boxes and consist of two biophysical components (grassland and livestock) and one management component (grazing manager). The functions of the components are shown in italics and the communication necessary to allow these functions to be preformed are in normal type. In this instance, the grazing manager has the task of applying nitrogen fertiliser and adjusting the livestock present on a continuously-grazed field to maintain a given target herbage mass. If the grazing manager is to perform its function of applying N fertiliser, it needs to exchange information with the grassland at periodic intervals whilst if it is to maintain herbage mass at the target, it needs to exchange information with the livestock module at weekly or daily intervals.

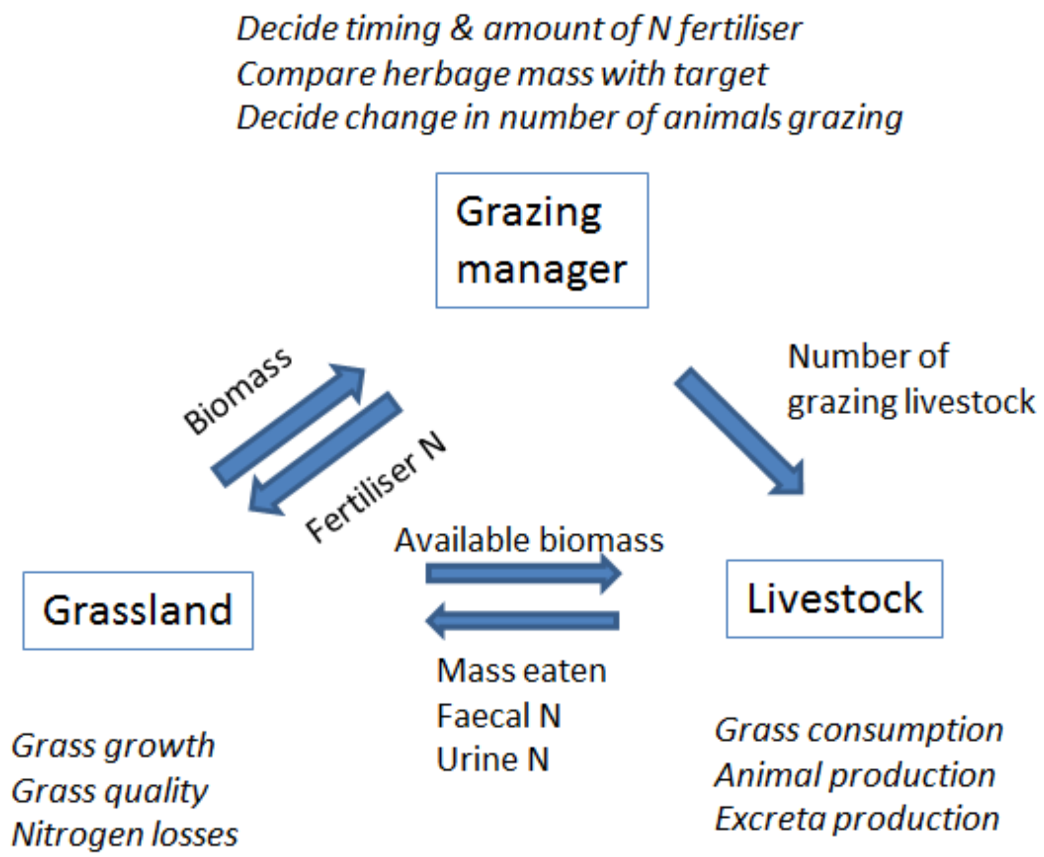

Fig 1 Simple example of flows of information and module functions. Arrows indicate flows of information, text in italics indicate functions.

Survey of existing models

Since existing farm-scale models have already had to address these issues, a survey was undertaken of the following models:

IFMS (USA)
DairyMod (AUS)
FASSET (DK)
Farmsim (F)
FarmAC (EU)
HolosNor (N)
SIMSDAIRY (UK/ES)

Melodie (F)
AgRECalc (UK)
SFarMod (UK)
Dairywise (NL)
These models were characterised as dynamic, static or hybrid. A static model was defined as one in which ….

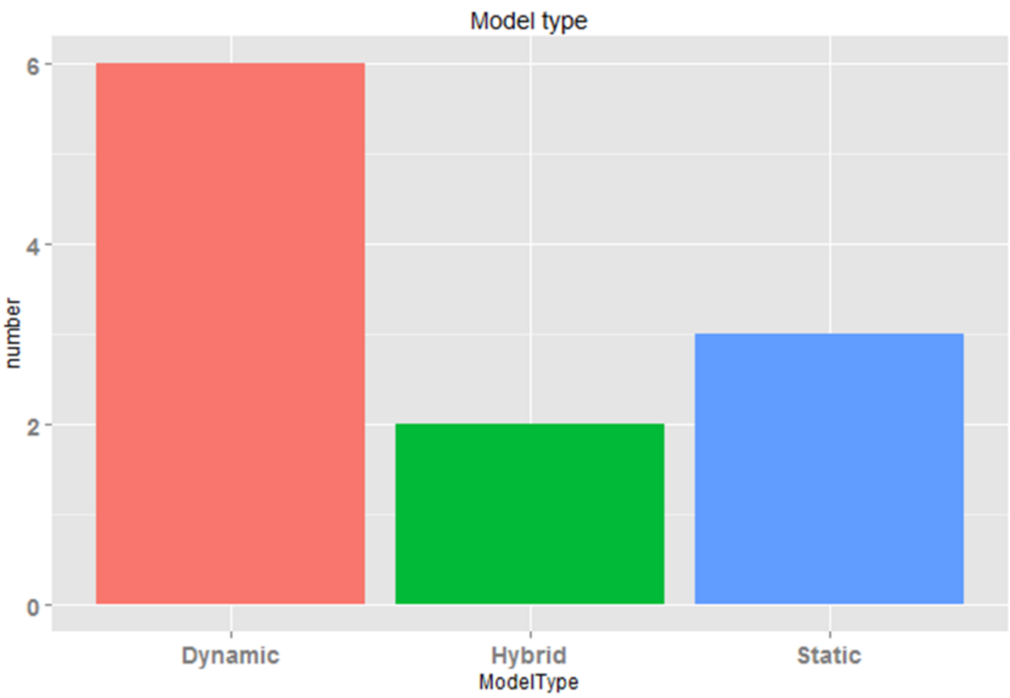

Fig 2 Model types represented in survey

The following structural information was required by most or all models:
Livestock type (e.g. dairy cattle)
Livestock group (e.g. early lactating)
Land area available
Soil type
Availability of irrigation
Location of fields, relative to farm buildings
Type of animal housing (e.g. freely-ventilated, solid floor)
Type of manure storage (e.g. slurry tank)

Only a minority of models required information about feed stores or other structures.

The outputs provided by a majority of models at the farm scale were:
Direct GHG budget.
Indirect GHG budget
C budget
N budget

Analysis of Components

Livestock

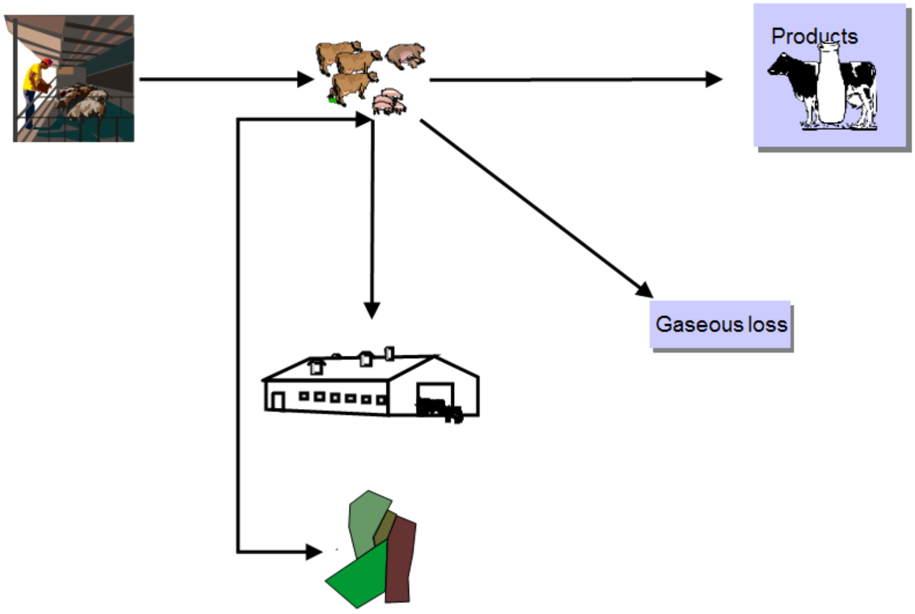

Fig 3 Flows of information for livestock

Farm survey results

	Dynamic	Static
Input		
Feed choices	*	*
Digestibility	*	
Meteorology	(*)	
Outputs		
Milk yield	*	*
Excreta	multiple	single
CH4	*	*
CO2	*	*
Frequency (in/out)	Day/month	Season/year

Multiple = multiple mass units
(*) = many but not all

Issues discussed

Prediction of intake from feed choices

Most models did this. The choices were made on the basis of energy requirement and sometimes also protein requirement.

Maximum intake was determined by a variety of (country-specific) means that took account of rumen fill.

Concentrate feeds were always consumed first, with roughage feeds next.

Digestibility depends on the chemical composition of the organic matter. The maximum digestibility depends on the lignin content. Starch and sugars are immediately digestible. The extent to which other forms of organic matter (cellulose and hemi-cellulose) is degradable in the rumen depends on residence time.

Estimation of milk yield or growth

All are made on the basis of energy requirement and sometimes also protein requirement.

Estimation of enteric CH4

Depends on the amount of organic matter is digested in the rumen. This depends on the intake of organic matter and the extent to which organic matter is degraded in the rumen (see under Prediction of intake).

Information concerning excreta (quantity and quality)

Total ammoniacal N (TAN) is required for NH3 emission calculations

Total N is required for N2O emission calculations and the calculation of organic N (total N – TAN)

Organic matter is required for calculation of CH4 and CO2 emissions

Animal housing

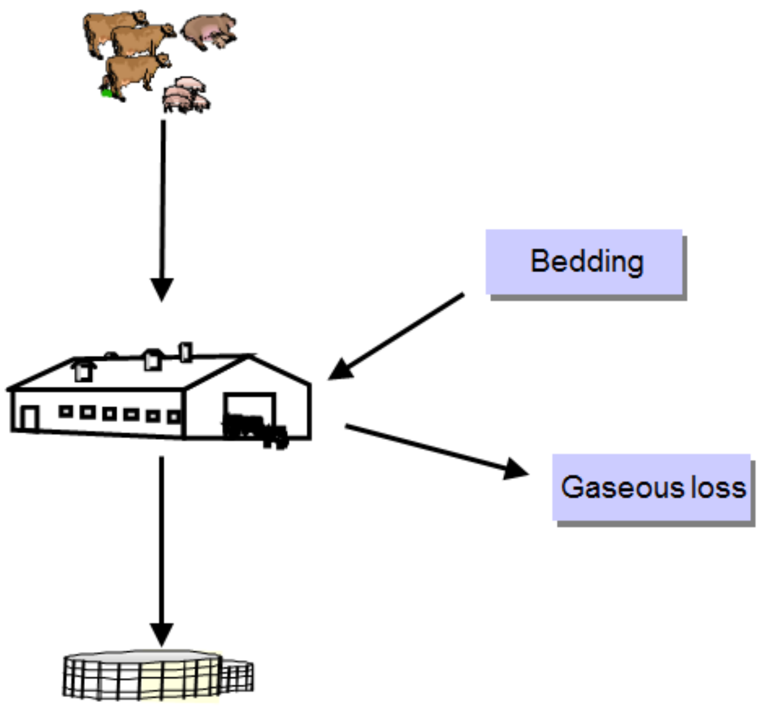

Fig 4 Flows of information for animal housing

Farm survey results

Housing	Dynamic	Static
Input		
Excreta	multiple	single
Meteo	(*)	
Outputs		
Manure	multiple	single
NH3	*	(*)
N2O	*	(*)
N2	*	(*)
CH4	*	(*)
CO2	*	(*)
water	(*)	
Frequency (in/out)	Day/month	Season/year

Items discussed

How do dynamic models calculate NH3 emissions?
Some use a dynamic approach, some static and some a mixture

Do dynamic models consider manure in housing as part of storage?
Unclear question. The models calculate the emission as a function of the housing temperature and ventilation but report it as part of the storage losses.

Is there a value in explicitly including housing in static models?
Yes, because it allows mitigation measures to be more easily investigated (the applicable measures are different for housing and storage)

Most dynamic models took account of elements added in bedding and spilt/waste feed.

Manure storage

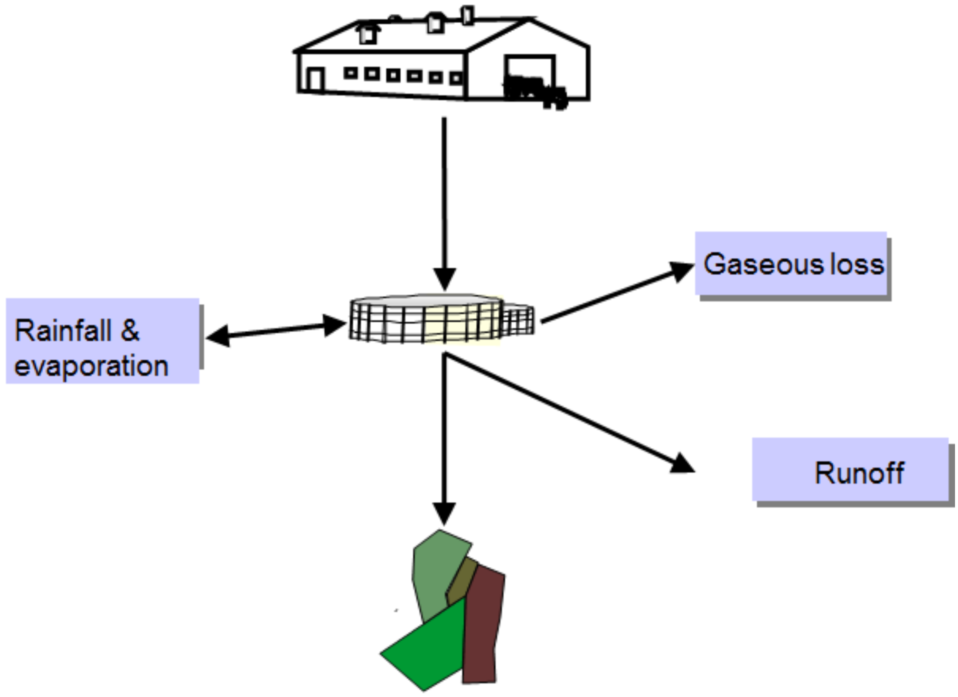

Fig 5 Flows of information for manure storage

Farm survey results

Manure storage	Dynamic	Static
Input		
Manure	multiple	single
Meteo	(*)	
Outputs		
Manure	multiple	single
NH3	*	*
N2O	*	*
N2	(*)	
Other C&N	*	
CH4	*	*
CO2	*	
water	(*)	
Frequency	Day/year	Season/year

Items discussed

How do models calculate NH3 emissions?
Some use a dynamic approach, some static and some a mixture

How do models calculate N2O emissions?
All use IPCC

Value of modelling N2 emissions
Some do, some do not. Models use a multiple of N_2O emissions but the actual multiple varies

How do models calculate CH4 and CO2 emissions?
Some use a dynamic approach, some static and some a mixture

The modelling of C and N flows in solid manure storage was considered problematic by all dynamic modellers.

Fields

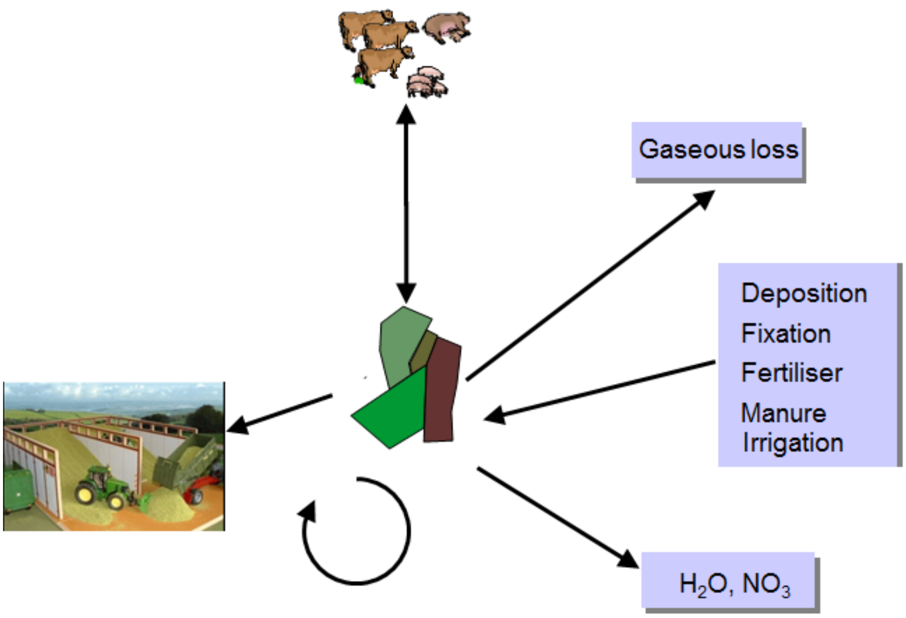

Fig 6 Flows of information for fields

Farm survey results

Field	Dynamic	Static
Inputs		
Manure	multiple	single
Manure application method	*	
Fertiliser	NH4&NO3	Total N
Water	*	
Meteo	(*)	

Field	Dynamic	Static
Outputs		
Production	multiple	single
Digestibility	*	
NH3	*	*
N2O	*	*
N2	*	
Other C&N	*	
CH4	*	*
CO2	*	
water	(*)	

The answer to the following questions:
How do models calculate NH3 emissions?
How do models calculate N2O emissions?
Modelling N2 emissions
How do models calculate CO2 balance?

Was "Some use a dynamic approach, some static and some a mixture".

Additional items discussed:
The N added in irrigation water was missing (this has been added to the diagram).
We discussed the calculation of nitrate leaching. Some models used a leaching fraction approach (i.e. leaching = fraction * (N input - (N output - gaseous N lost)). Others calculated leaching from water drainage and the concentration of nitrate in soil water.
We need to clarify how N fixation is calculated.
We need to know if a model assumes soil C and N is in steady-state at the annual scale.

Feed storage

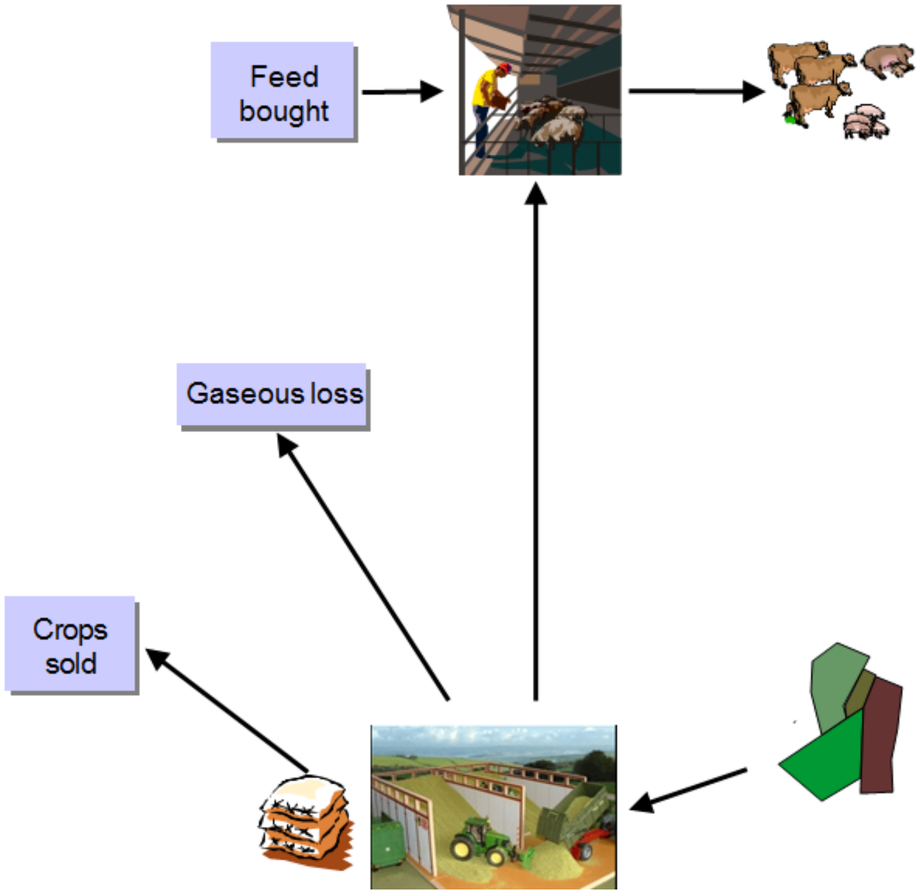

Fig 7 Flows of information for feed storage

Farm survey results

Few models included flows in/out of feed stores. Since there appear to be large losses of C (and possibly N) associated with especially silage making and storage, this appears to be an omission. For C, it is clear that the fermentation process will lead to an emission of CO_2. For N, the type of loss is less clear; although silage can contain significant concentrations of TAN, there should not be much NH_3 emission, since the pH of silage is low.

Losses associated with harvesting, drying (hay) and wilting (silage) are field processes.

Other

Hardstanding and corrals (places were animals are kept at high density for short or longer periods). We need to know how these are handled. Likewise access roads.

Management

Farm management can be modelled in three main ways:

- A fixed plan
- A set of rules to set the plan
- An optimisation of resources allocation, according to constraints and an objective function

<u>Tactical farm management</u>

Farm survey results

Tactical	Dynamic	Static
Replacement	*	*
Calving	*	
Conserved feed requirement	*	*
Crop rotation planning	(*)	
Cutting planning	*	
Fertiliser & manure planning	*	
Machinery planning	(*)	

Although the dynamic models generally included more modelling of tactical management, there were examples of dynamic models with fixed plans and static models with optimised resource allocation.

<u>Operational farm management</u>

Farm survey results

Operational	Dynamic	Static
Livestock		
Feed formulation	*	*
Purchase/sale	*	*
Mating	*	
Weaning	*	

Drying off	*	
Housing		
Ventilation	(*)	
Cleaning	(*)	
Manure storage		
Emptying	*	

Field		
Cultivation	*	
Sowing	*	
Fertilisation	*	
Manuring	*	
Cutting	*	
Silage making	*	
Grazing	*	

A fixed plan is commonest for static models whereas the two other methods are used to varying degrees in dynamic models.

Next Steps

The next steps to produce the paper are:

- To clarify some responses from some modellers.
- Survey the functions of farm modules (one or two sentences per function).
- Analyse results of the function survey.
- Draft a new version of the paper.

Acknowledgements
This paper is a contribution to the FACCE MACSUR knowledge hub