An introduction to LIVSIM

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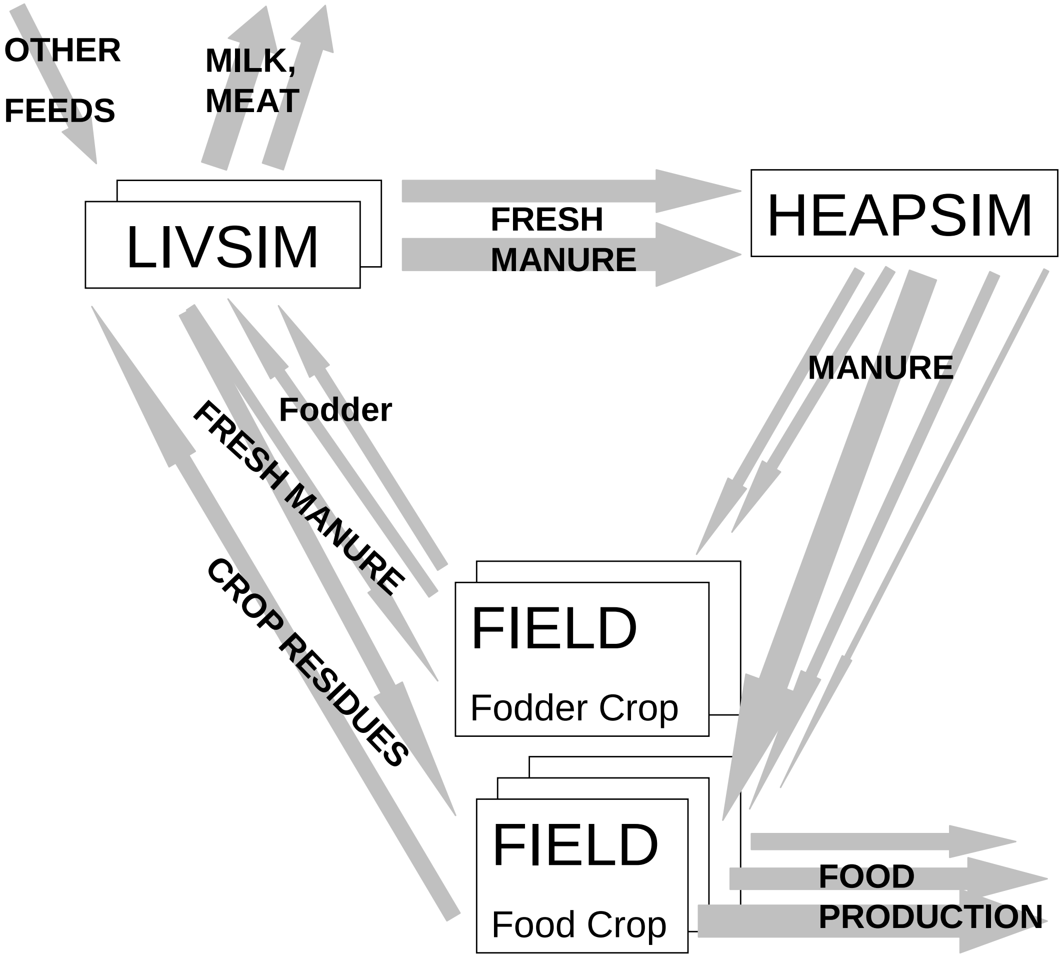
LIVSIM in context - FARMSIM

- NUANCES-FARMSIM is a dynamic model for exploration of questions related to strategic, long-term management at farm scale.
  - Crop + Soil → FIELD
  - Livestock → LIVSIM
  - Manure management → HEAPSIM
  - Miscellaneous → GrassSIM
- The purpose is to identify options for optimizing the use of the farm resources, instead of maximisation of one singe production trait.

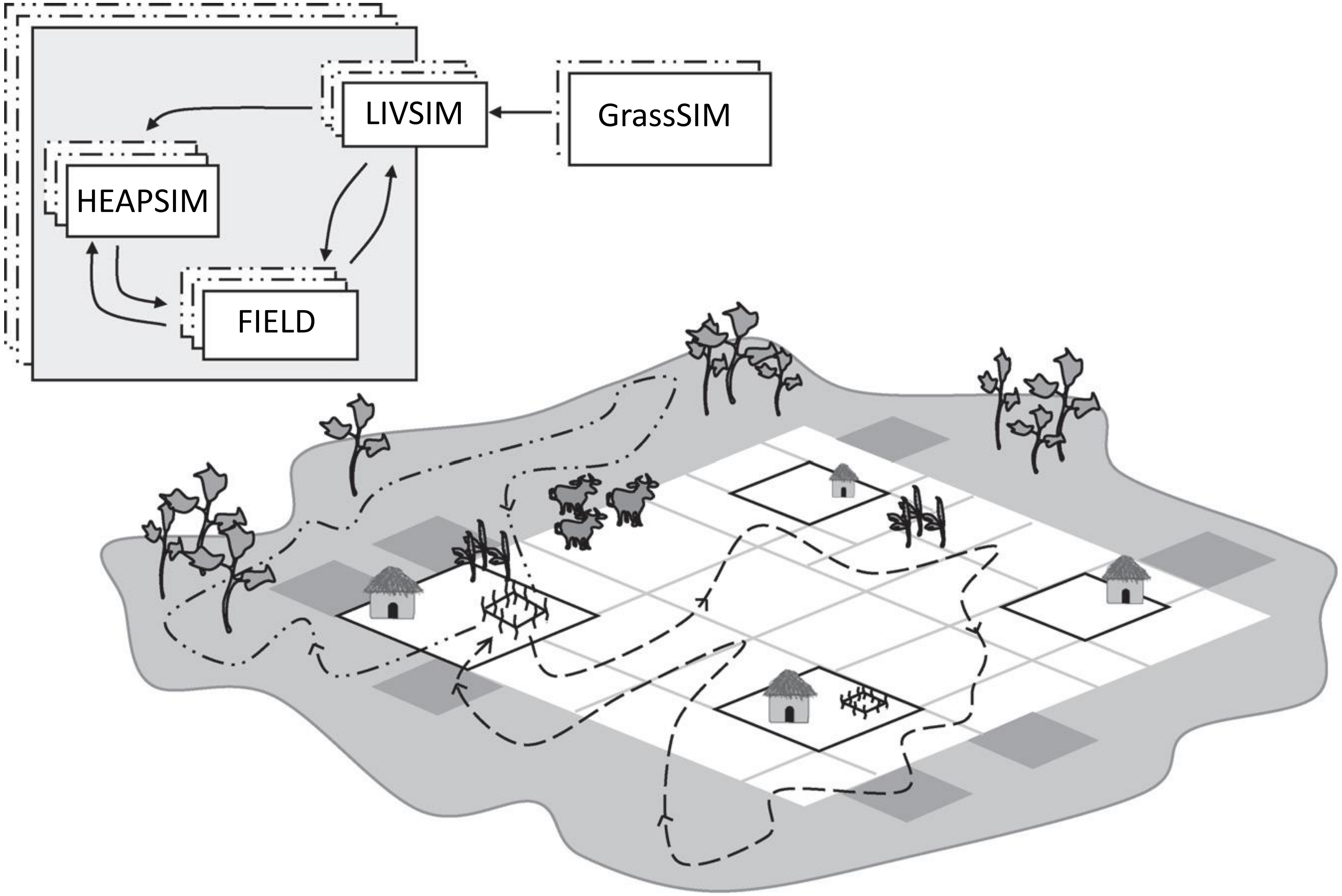
LIVSIM in context – FARMSIM (van Wijk et al. 2009)



LIVSIM in context – FARMSIM (Rufino et al. 2011)

- Village-level interactions between farm types and climate variability in a communal area of NE-Zimbabwe
  - What are the size and dynamics of the flow of nutrients and C?
  - How do management practices affect the size and dynamics of these flows?
  - What is the effect of climate variability on farm- and village level interactions?
  - When does competition for organic resources become most critical for cattle and crop production?
  - What are the options for intensification?

LIVSIM in context - FARMSIM



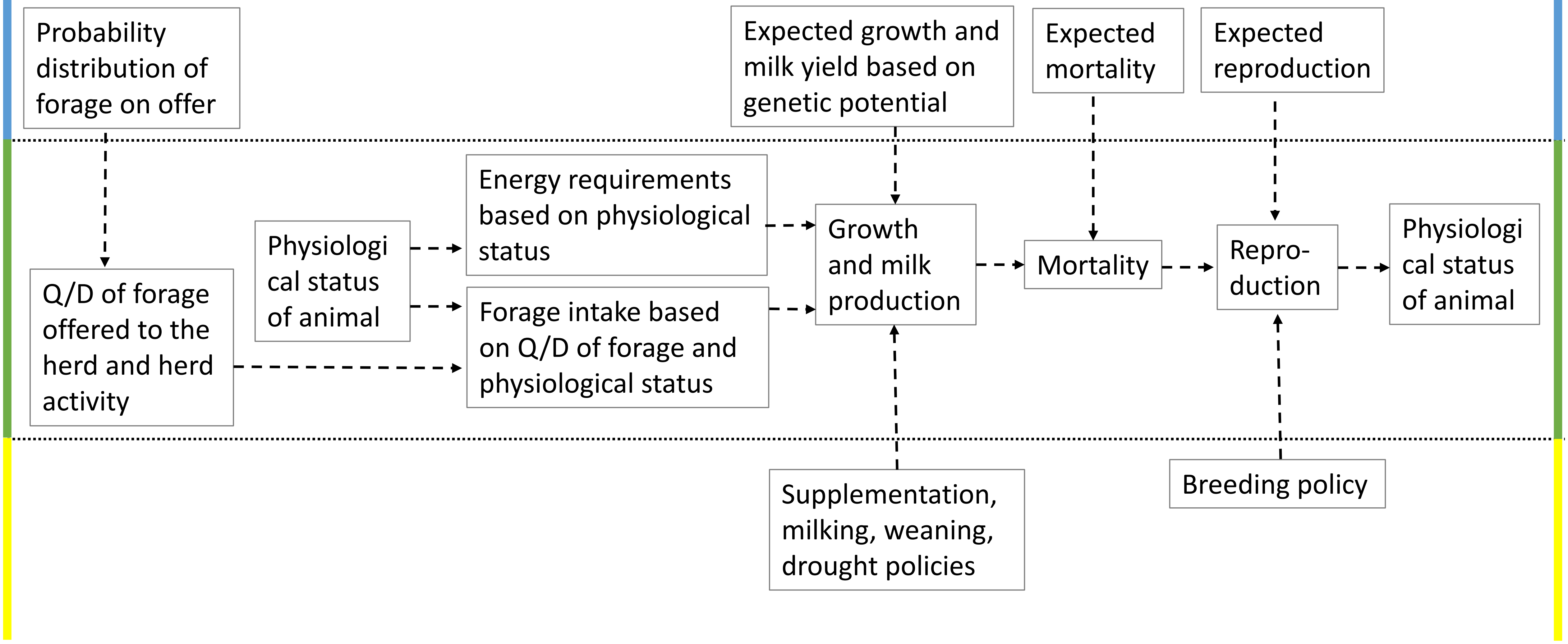
LIVSIM – the beginning

- The basis for LIVSIM is the model of Konandreas and Anderson (1982).
  - This model was developed specifically for the African context.
  - “Cattle herd dynamics: an integer and stochastic model for evaluating production alternatives.”
    - Integer: the model treats animals in the herd as individual entities.
    - Stochastic: reflects the limited understanding of the processes involved.

Eight essential features (Konandreas and Anderson, 1982)

1. Reproduction, growth and death should be determined as functions of other factors embedded in the model.
2. Limited understanding of some processes involved implies stochasticity.
3. Validation requires that the structures in the model should be based upon data readily observable.
4. The model must be time dynamic: timing of events and of responses to events.
5. Animals must be treated as separate entities.
6. Allow simulation of different management options.
7. Multiple objectives of farmers means that optimization models may not be well-suited.
8. A model should be designed so that its components can be modified, added to, or deleted with a minimum of effort.

LIVSIM – the beginning (Konandreas and Anderson, 1982)



LIVSIM – the beginning

- LIVSIM differs from the model by Konandreas and Anderson in a number of ways:
  - Nutritive requirements calculations according to AFRC (1993); ME and MP.
  - Feed intake is based on Conrad *et al.* 1966.
  - The model takes into account excreta production.
  - Other decision making rules are implemented.

Reproduction, growth, and death

- Probability of conception:

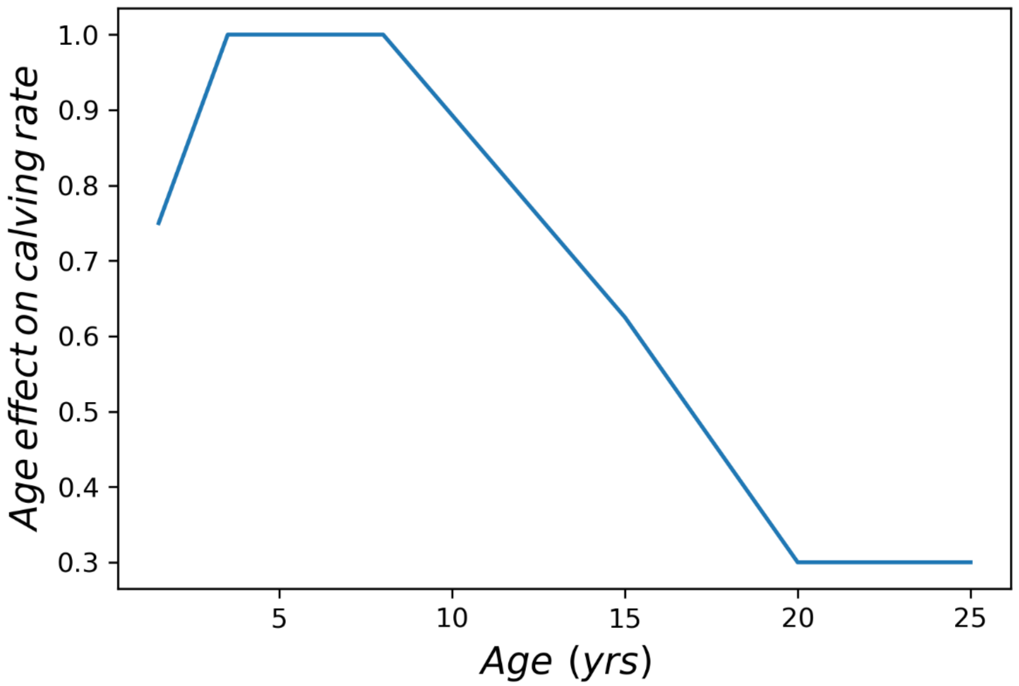
$$P_c = P_M * m_f * m_n * m_c$$

- Gestational requirements (ME + M … C (1993).

$$P_M = 1 - (1 - P_A)^{\frac{1}{12}} * m_{age}$$

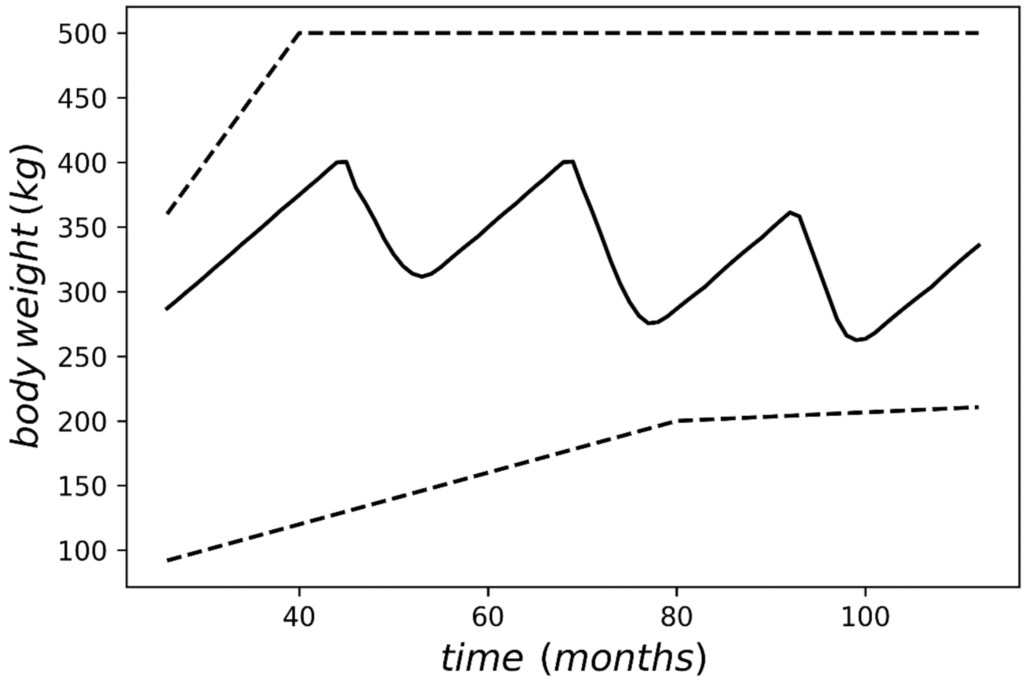
$$bci = \frac{W - W_{min}}{W_{max} - W_{min}}$$

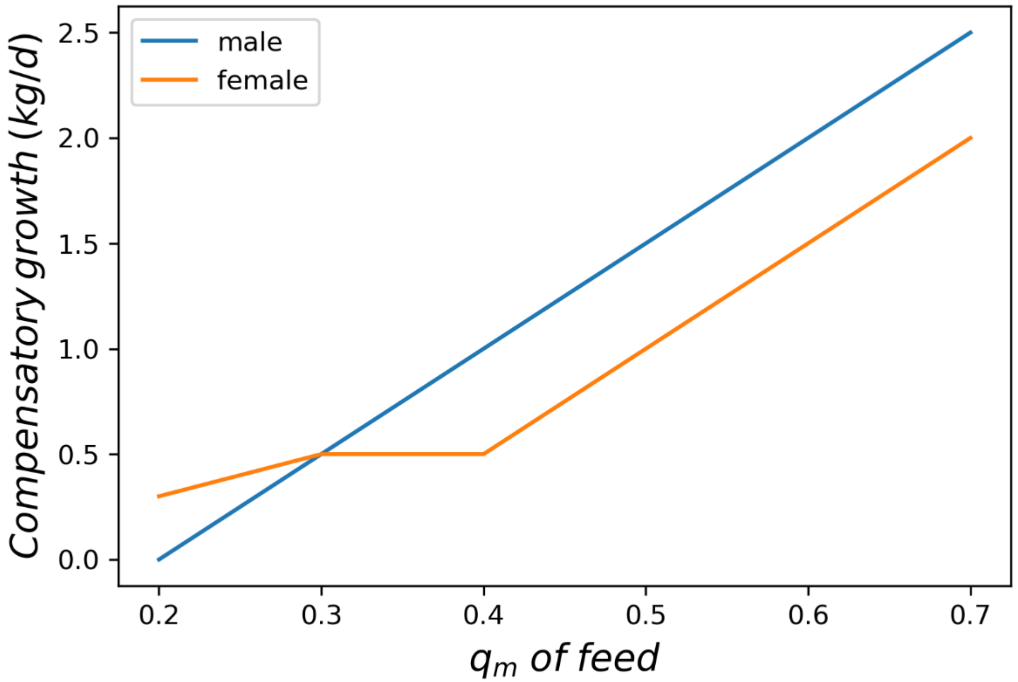
- Sex of the calves is determined sto



Reproduction, growth, and death

- Potential growth: $\min(growth_{potential}, growth_{compensatory})$
- Compensatory gain depends on metabolisability of feed (q_m):





Reproduction, growth, and death

- Voluntary roughage intake according to Conrad (1964) :

$$Intake = \frac{0.0107 * BW}{1 - DMD}$$

- Concentrates and milk (before weaning) are assumed to be consumed completely.
  - Feeding preference: (milk) > concentrates > roughage
- ME and MP contents of feed calculated according to AFRC (1993).

Reproduction, growth, and death

- Nutritive requirements according to AFRC (1993):

$$ME_i = \frac{E_i}{kE_i} \qquad MP_i = \frac{NP_i}{kP_i}$$

- Example:

$$ME_{lactation} = \frac{yield_{milk} * EV_{milk}}{kE_{lactation}} \qquad MP_{lactation} = \frac{yield_{milk} * TP_{milk}}{kP_{lactation}}$$

$$EV_{milk} = 0.0406 * fat_{milk} + 1.509 \qquad TP_{milk} = \frac{CP_{milk} * 10 * 0.95}{1.03}$$

Reproduction, growth, and death

- Total requirements:

$$ME_{total} = \sum_{i=1}^{n} ME_i \qquad MP_{total} = \sum_{i=1}^{n} MP_i$$

- Balancing act: is intake sufficient to meet total requirements?
  - If intake >= requirements: potential production
  - If intake < requirements: decisions!

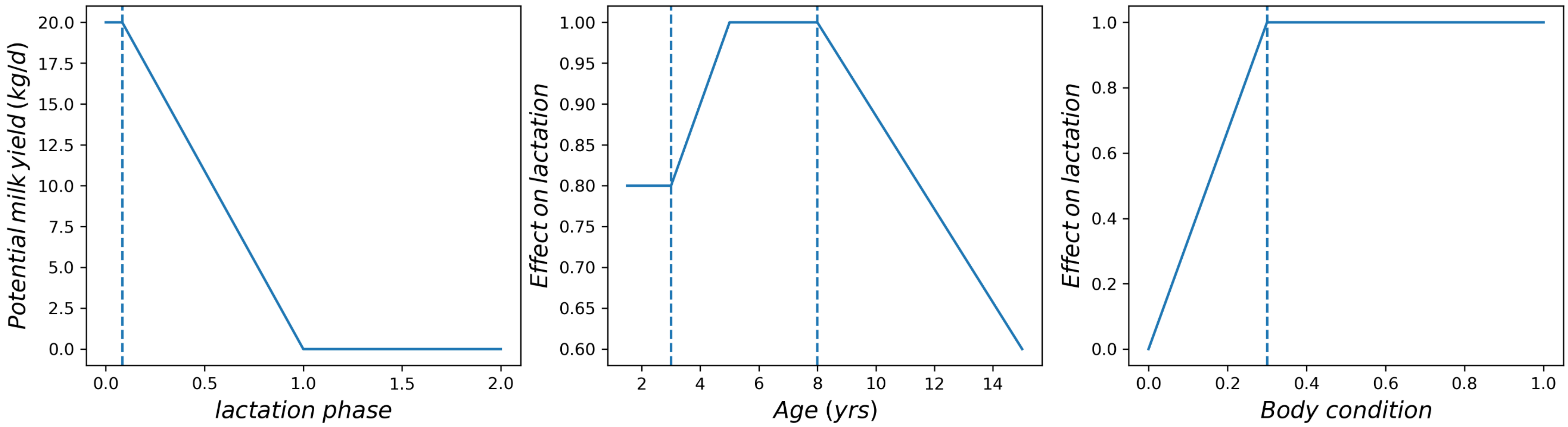
Reproduction, growth, and death

- If total ME or MP intake is insufficient processes are prioritized:
  - gestation > lactation > maintenance > growth

```
if intake > (gestation + lactation + maintenance):
    little_growth
else:
    weight_loss
    if lactating:
        if weight_loss > treshold:
            if intake > (gestation + maintenance):
                limited_milk_production
            else:
                stop_milk_production
    if weight_loss > max_allowed:
        cow_dead
```

Reproduction, growth, and death

- Potential milk production depends on a breed specific lactation curve, the age of the animal and the body condition index.

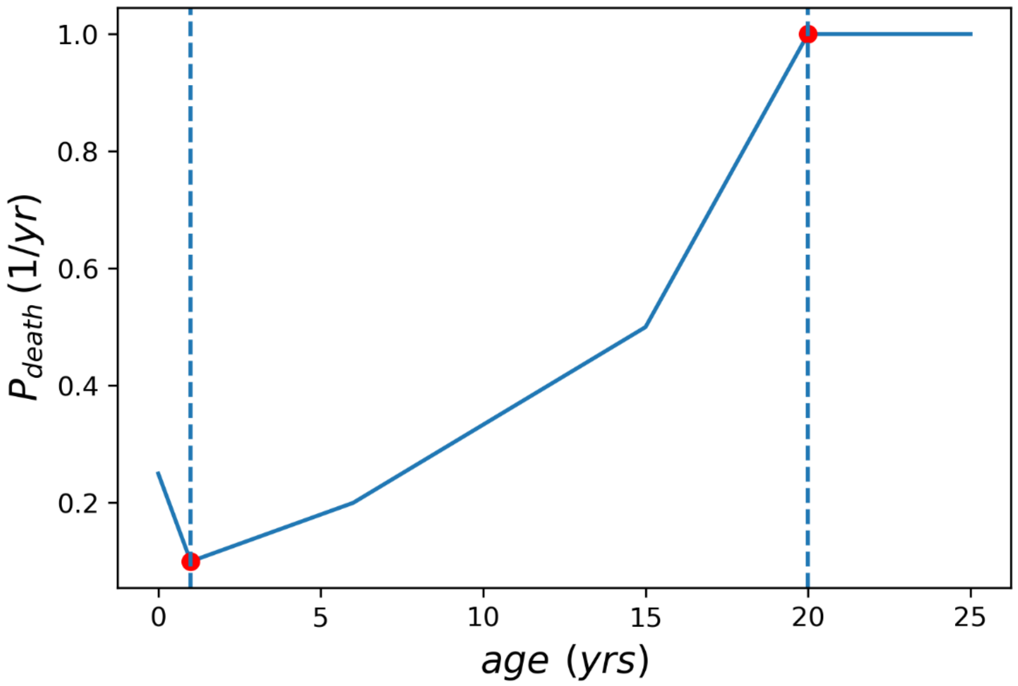


Reproduction, growth, and death

- Excreta production depends on DMD for the amount of manure produced.
  - N-concentration in manure depends on protein in feed according to AFRC (1993).
  - P-, and K-concentrations are calculated according to Efde (1996).
- Manure from the livestock can be used to fertilize fields.
- Manure management is a part of HEAPSIM and not taken into account in LIVSIM.

Reproduction, growth, and death

- Animals can die either by starvation or by ‘natural’ causes.



$$P_M = 1 - (1 - P_A)^{\frac{1}{12}}$$

Herd management

- Management decisions can be made regarding feeding and herd composition.
  - Let feed supplementation depend on life stage.
  - Prioritize certain feed types to certain animals.
  - Set replacement conditions (age, lactation, period open).
- Herd and feed management in LIVSIM aim to be easily adaptable to fit specific case studies.

Model design / code quality / documentation

- The current version of LIVSIM is written in Python:
  - Python encourages writing easily readable code (PEP-8).
  - Python was designed to make coding fun (hence the numerous references to Monty Python).
  - Python is easy to learn and has a large (and rapidly growing) user-base.
- Modularity of LIVSIM (and FARMSIM) is emphasized by OOP:
  - Each individual part of the model (animal, soil, crop, field, heap, feed-type, ...) is a self-contained unit; an object.
  - Functionality of an object is defined in *methods.*
  - A method, in a way, can be compared to a paragraph in a text; it should have only one topic (i.e. one job to do).

Model design / code quality / documentation

```
def conception_probability(self):
    ''' The probability of conception (1/month).

    See [2] A2.2, eq. 3 and 4.
    '''
    pot = self.potential_conception_probability
    c1 = self.can_conceive_given_maturity
    c2 = self.can_conceive_given_postpartum
    c3 = self.can_conceive_given_bull
    c4 = self.can_conceive_given_body_index

    return pot * c1 * c2 * c3 * c4
```

Model design / code quality / documentation

```python
def milk_yield(self):
    ''' The milk production (kg/month). '''
    if self.is_lactating:

        c1 = self.milk_condition_factor
        c2 = self.milk_age_effect_factor

        pot = self.milk_yield_potential

        return max(0, c1 * c2 * pot)
    else:
        return 0
```

References

- Konandreas P, Anderson FM, (1982). Cattle herd dynamics: an integer and stochastic model for evaluating production alternatives. *ILCA Research Report No. 2.*
- Rufino MC, Dury J, Tittonell P, van Wijk MT, Herrero M, Zingore S, Mapfumo P, Giller KE, (2011). Competing use of organic resources, village-level interactions between farm types and climate variability in a communal area of NE Zimbabwe. *Agricultural Systems* 104: 175-190.
- Van Wijk MT, Tittonell P, Rufino MC, Herrero M, Pacini C, de Ridder N, Giller KE, (2009). Identifying key entry-points for strategic management of smallholder farming systems in sub-Saharan Africa using the dynamic farm-scale simulation model NUANCES-FARMSIM. *Agricultural Systems* 102: 89-101.