A mechanistic model to explore potential beef production of cattle breeds in contrasting climates

WaCaSa meeting 10-02-2014

Aart van der Linden, Simon Oosting, Gerrie van de Ven, Martin van Ittersum, Imke de Boer

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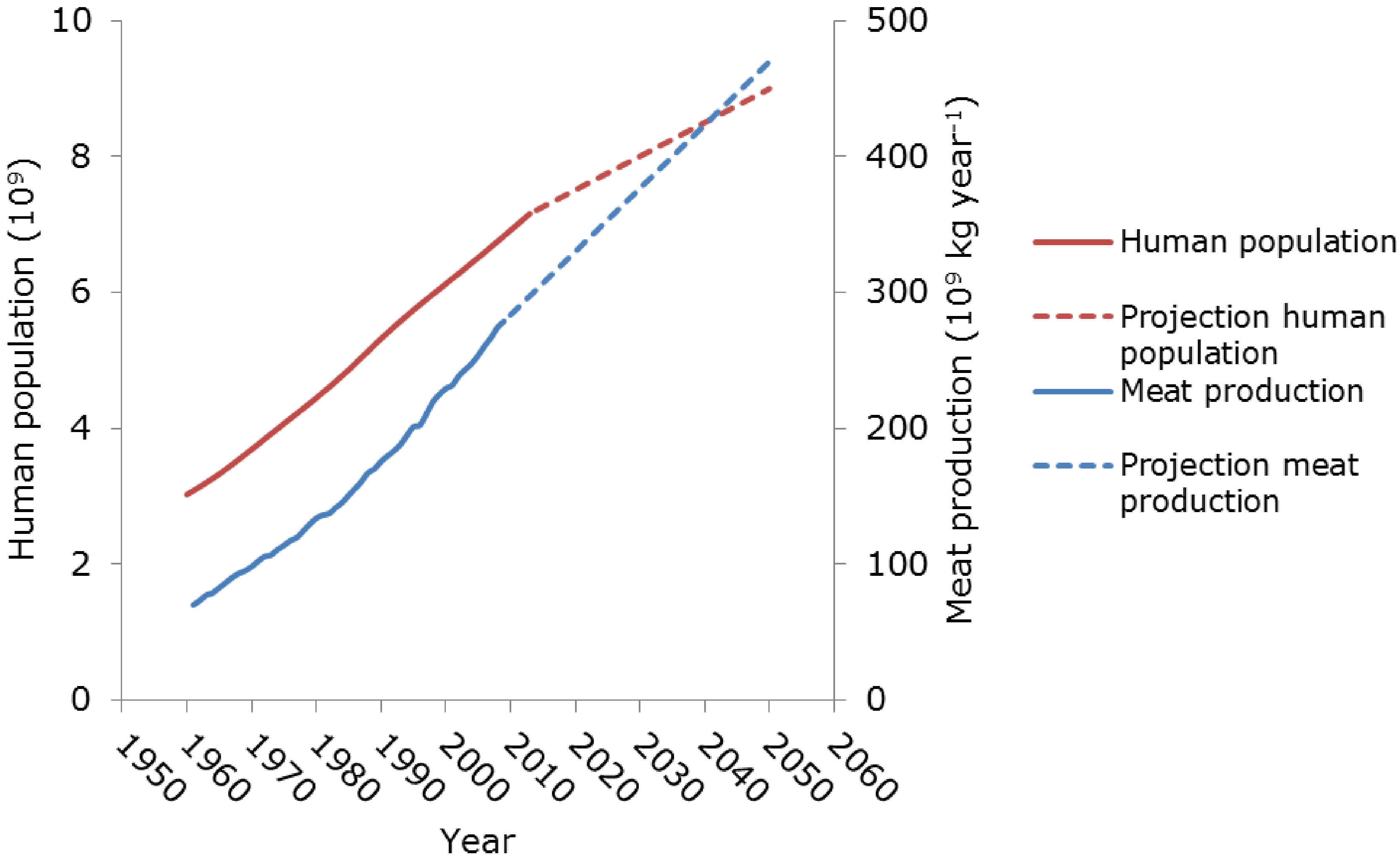
Introduction (1)



FAOSTAT (2013)

Introduction (2)

How to increase meat production?

1. Increase number of animals
2. Increase production per animal (intensification)

How much meat can be produced more per animal?

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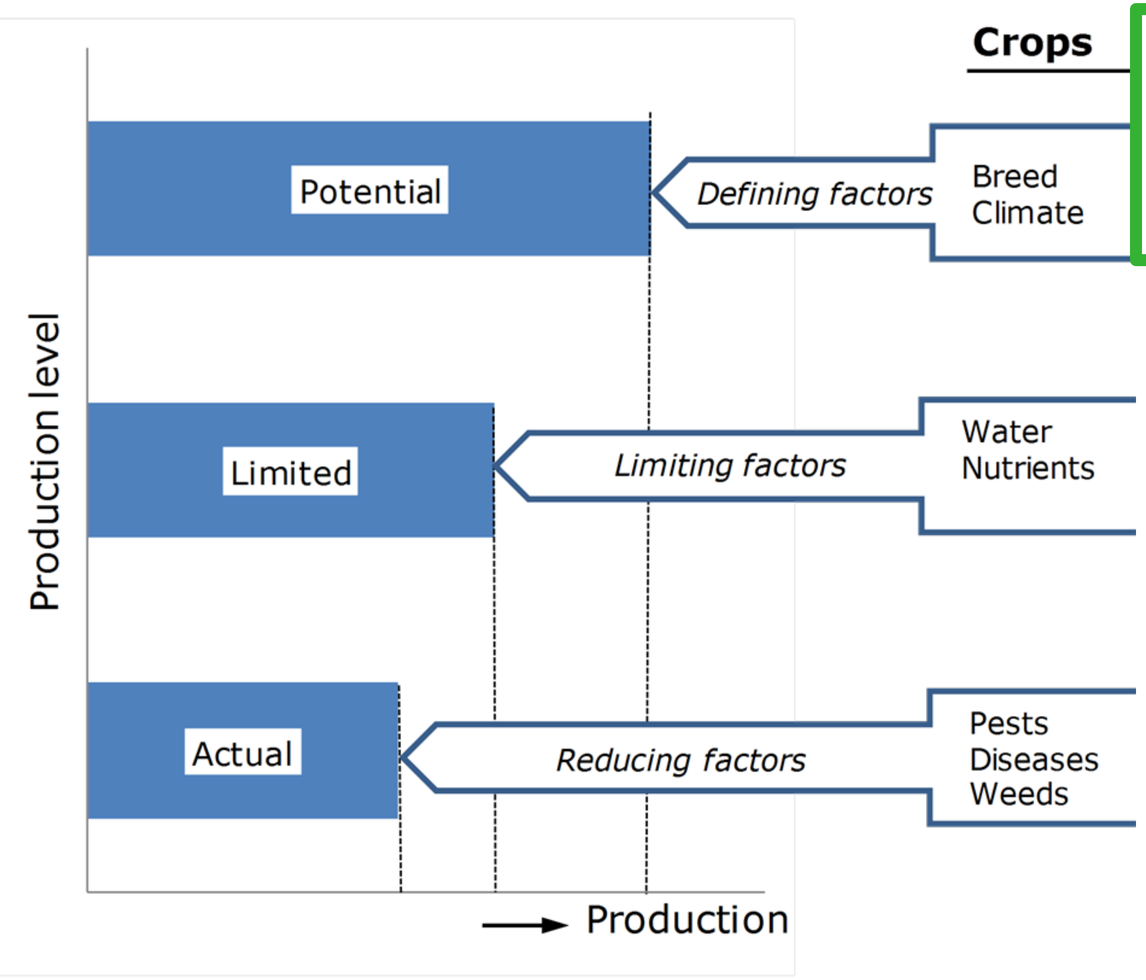
Introduction (3)

Production ecological concepts



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Van Ittersum and Rabbinge, 1997; Van de Ven et al, 2003

Introduction (4)

- Potential production: Genotype, Climate, and G x C
- Animal models
  - Either genotype or climate are not included
    - Genotype + Empirical climate correction (THI)
  - Mechanistic growth models → genotype
  - Mechanistic thermoregulation models → climate

Research objective

To assess and explore potential beef production

↑

To develop a mechanistic model that simulates potential production

Overview methodology

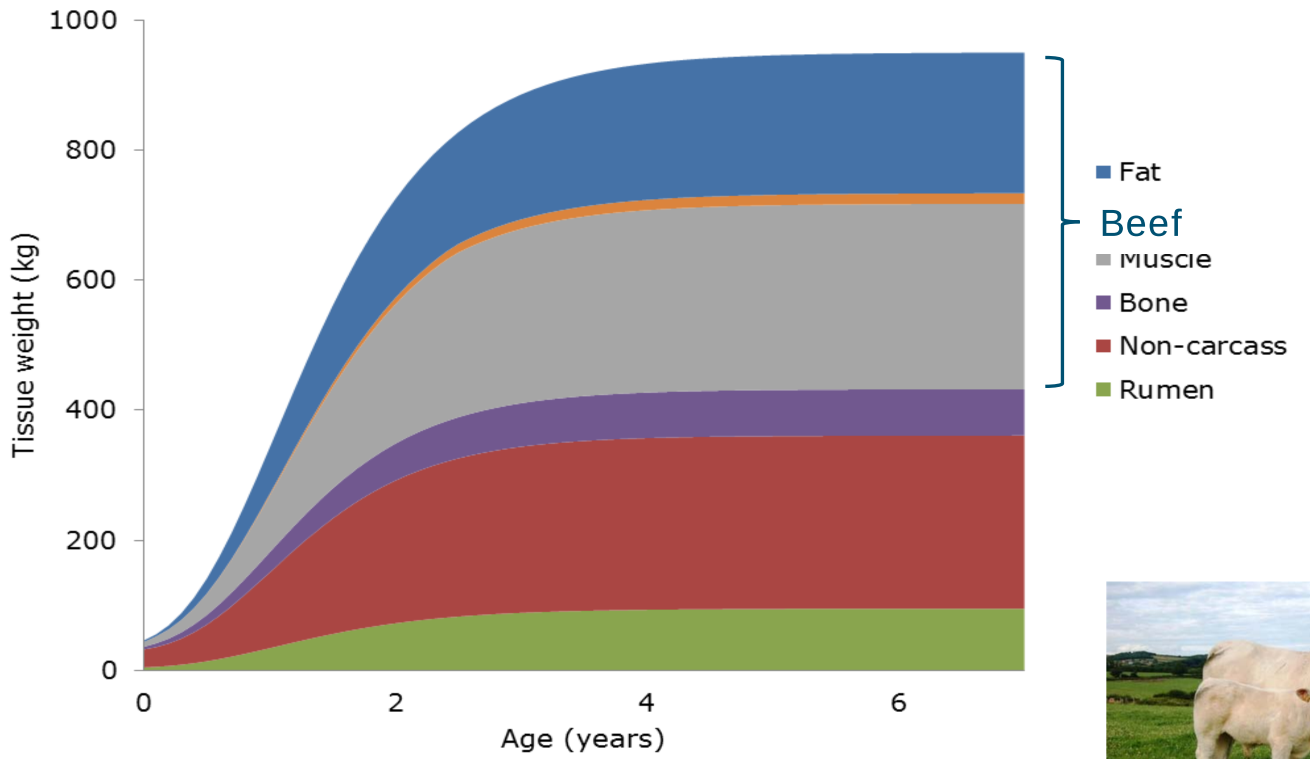
1. Modelling growth defined by genotype

2. Modelling growth defined by climate

3. Integration of genotype and climate

Methods (1) Genotype

- Net energy (NE) for growth



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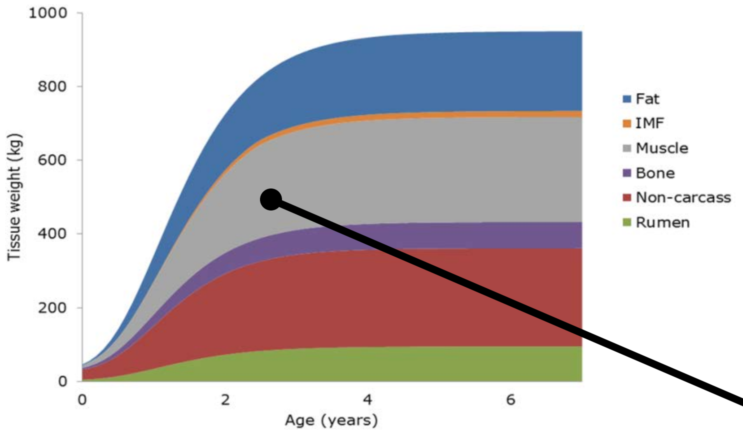
Methods (2) Genotype



$$E_m(t) = \frac{dM}{dt} \times (0.210 \times 23.8 + 0.005 \times 39.6)$$

- Example composition muscle tissue
  - Water 77.2 %
  - Ash 1.3 %
  - Protein 21.0 % ($23.8\ MJ\ kg^{-1}$)
  - Lipid 0.5 % ($39.6\ MJ\ kg^{-1}$)

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Methods (3) Genotype

- Net energy (NE) for growth
  - Protein accretion efficiency: 54% (NE → NE accr.)
  - Fat accretion efficiency: 74% (NE → NE accr.)
- NE for maintenance
  - $EBW^{0.75} \times 311$ kJ day^{-1}
- NE for pregnancy and milk production
- NE for physical activity
- Energy for digestion and absorption = Heat incr. of feeding (HIF)
  - Different for feeds (Chandler, 1994)
  - 30-70% of ME (Armstrong and Blaxter, 1956)

NE + HIF = ME

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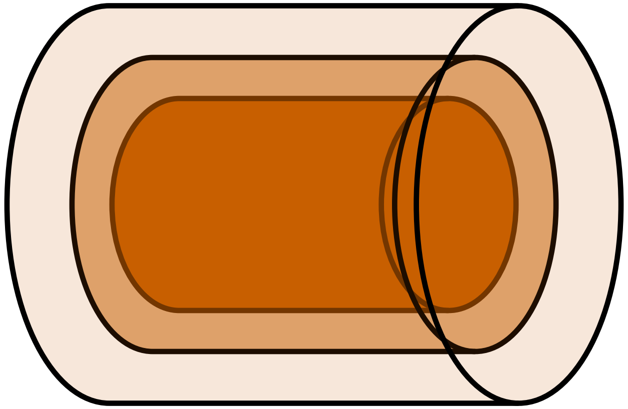
Methods (4) Genotype

$$ME_{tn}(t) = \quad (NE_{growth}(t) + NE_{maintenance}(t) + \; NE_{physical\ activity}(t) +$$

$$NE_{gest.\ tot.}(t_c) + NE_{milk}\left(t_p\right)) \times (1 + \left(\frac{fr.HIF}{1-fr.HIF}\right))$$

Methods (4) Climate



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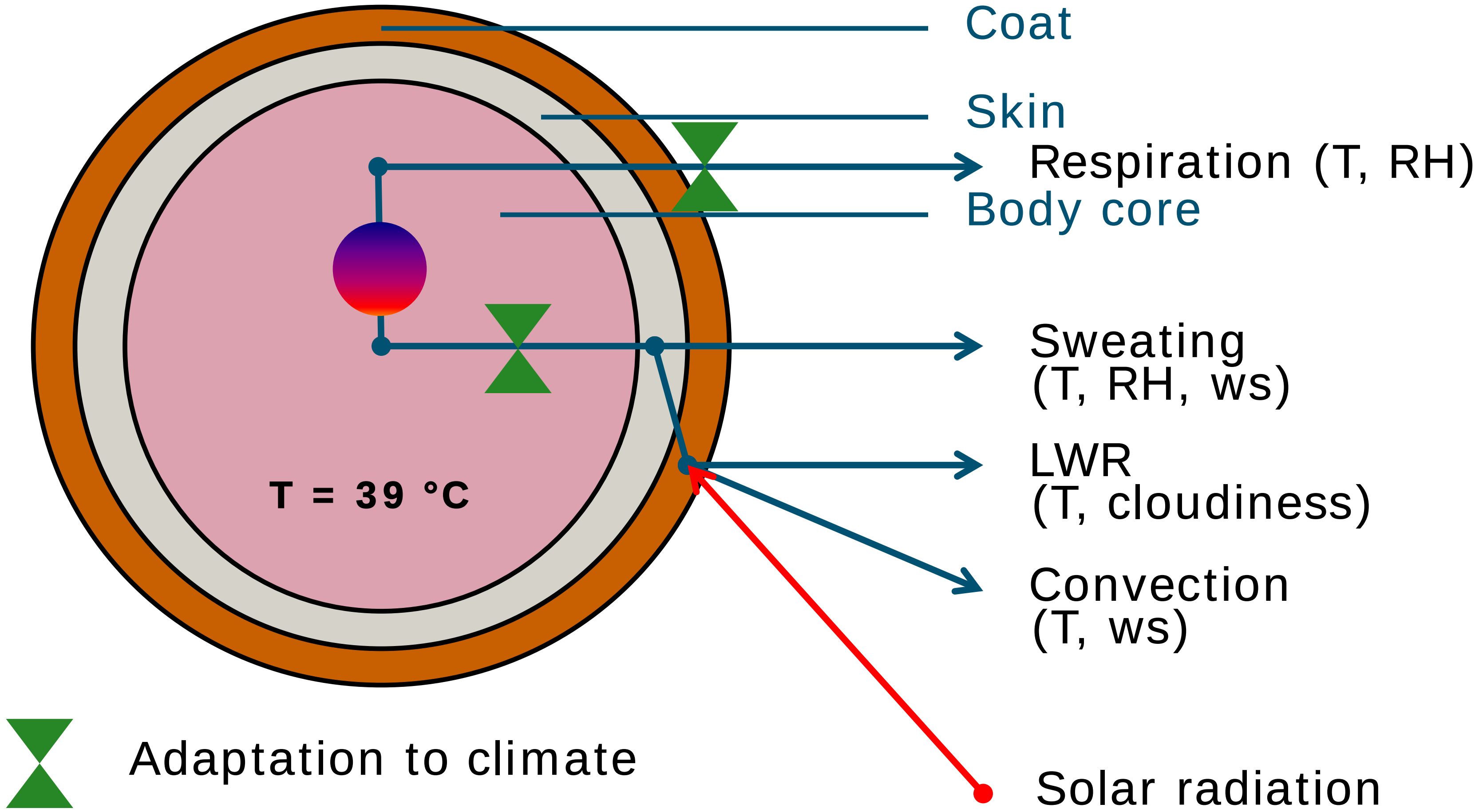
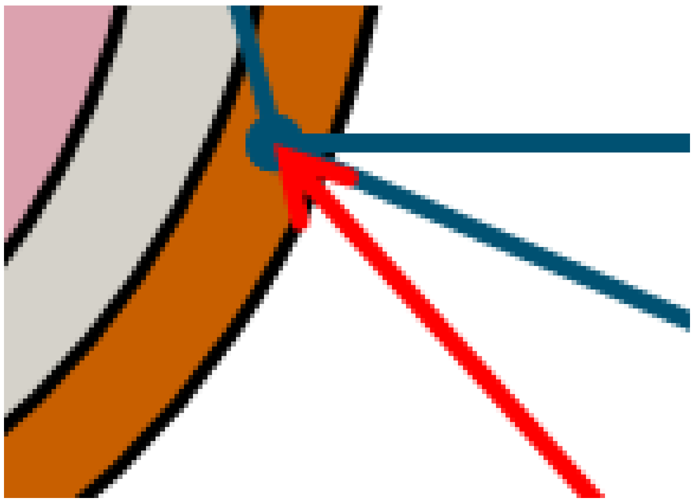
Methods (5) Climate

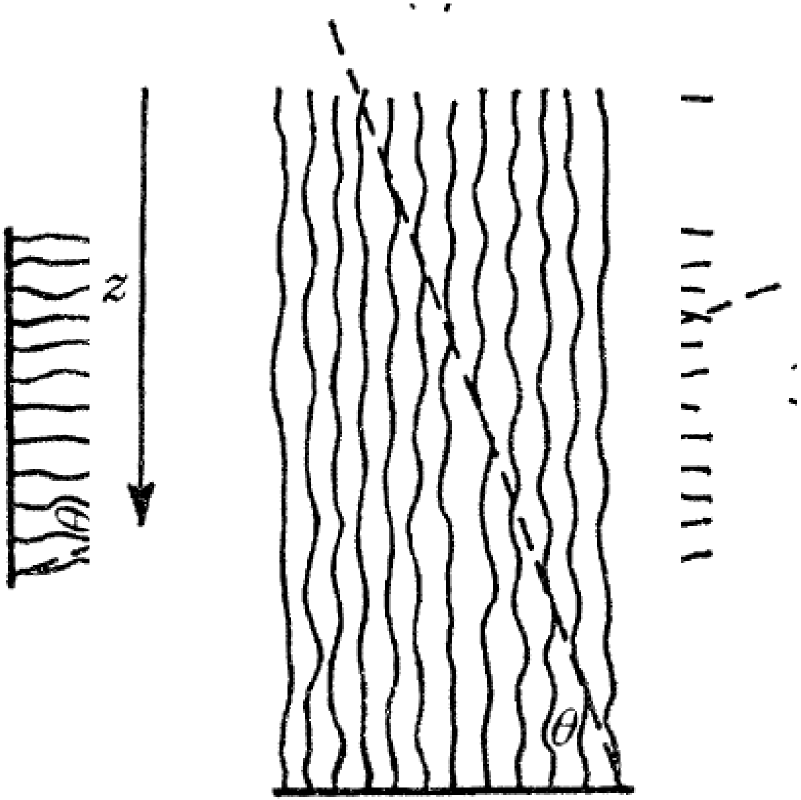
$$H_{metabolism} + H_{solar} = H_{resp} + H_{sweating} + H_{LWR} + H_{convection}$$



McGovern and Bruce, 2000

Methods (6) Climate

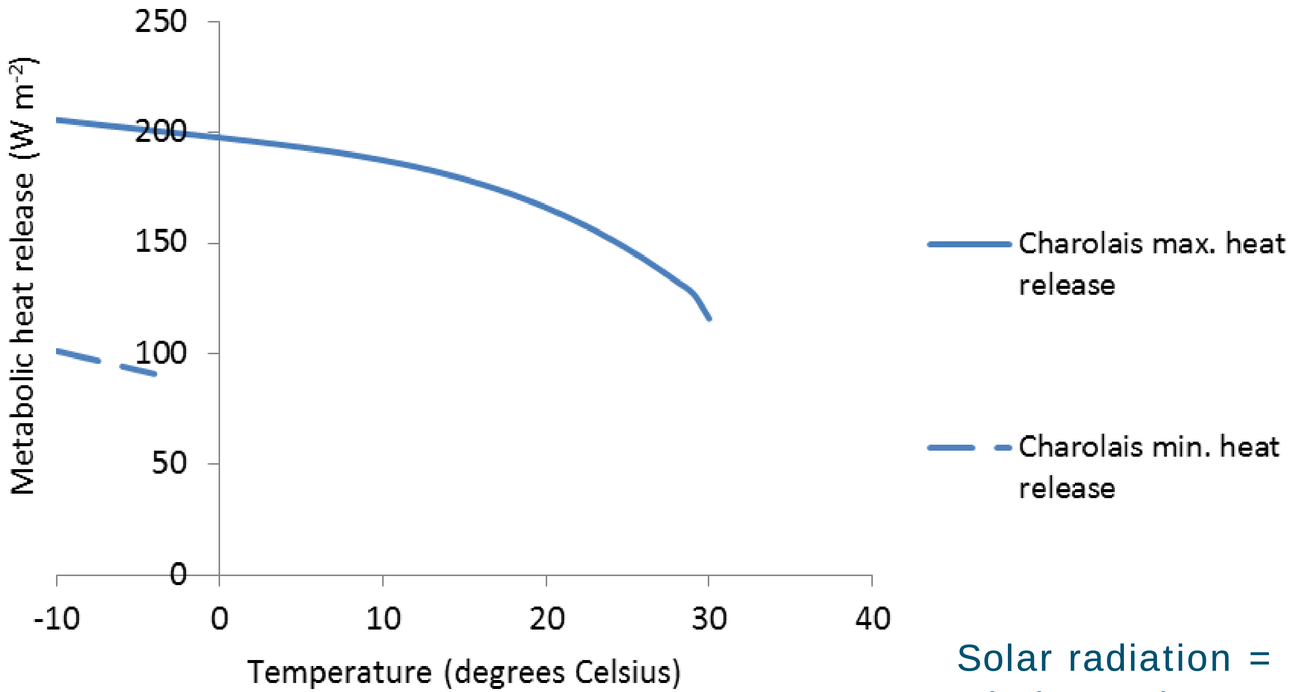




Cena and Monteith (1975)

Methods (7) Climate

For given weather conditions: maximum heat release vs. minimum heat release



Solar radiation = 25000 kJ m^2 (soil); wind speed = 0.5 m s^{-1}; RH = 90%; cloudiness = 2 Ω; total weight Charolais: 950 kg

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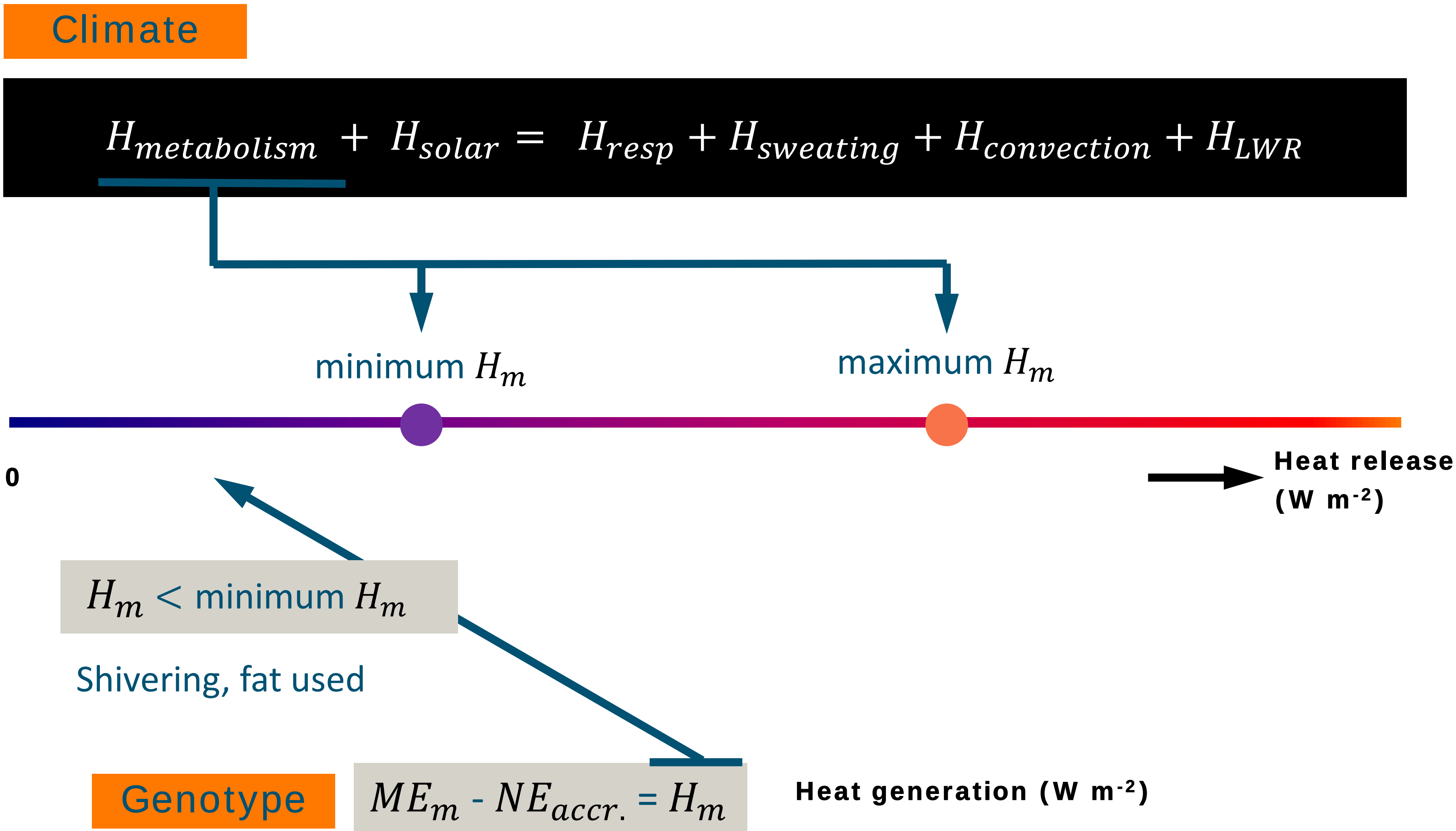
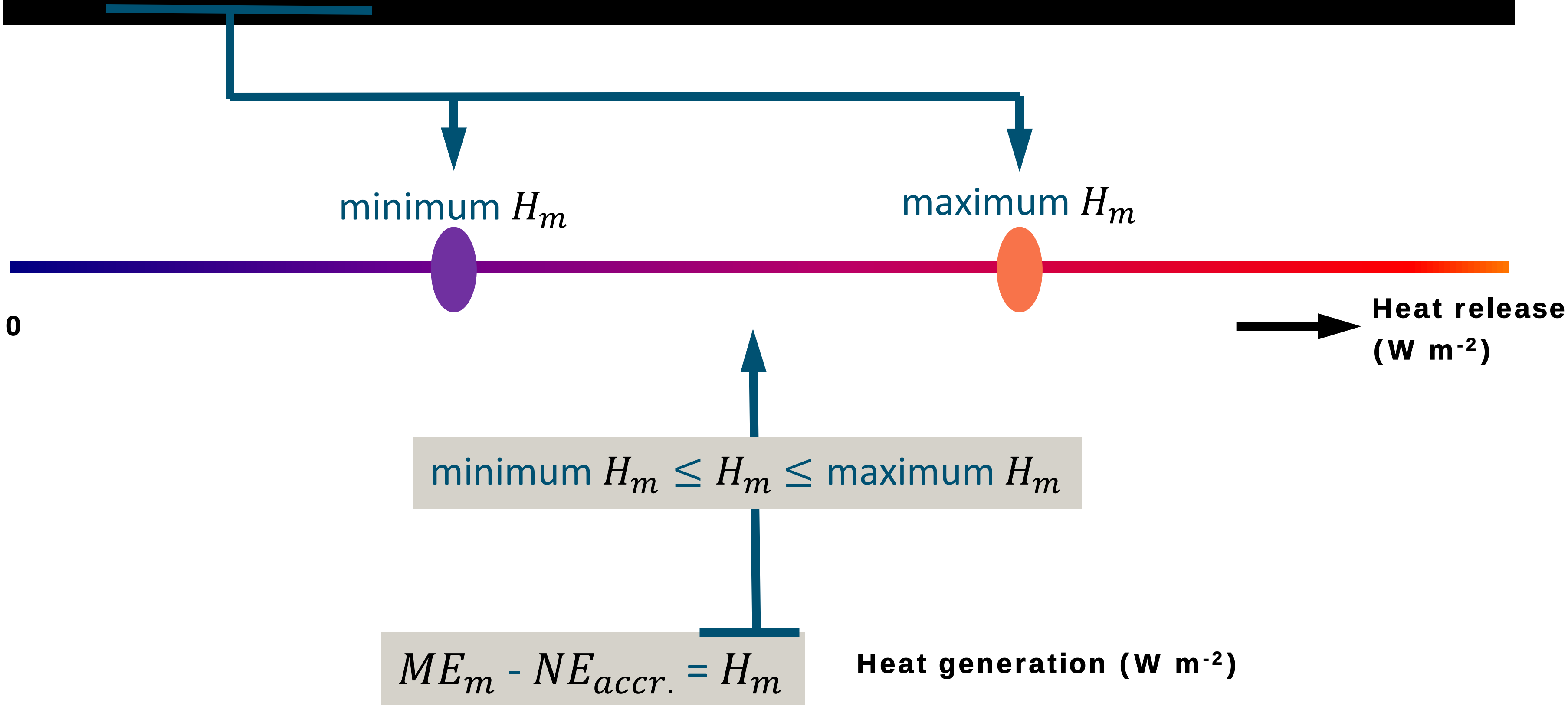
Methods (8) G x C interaction

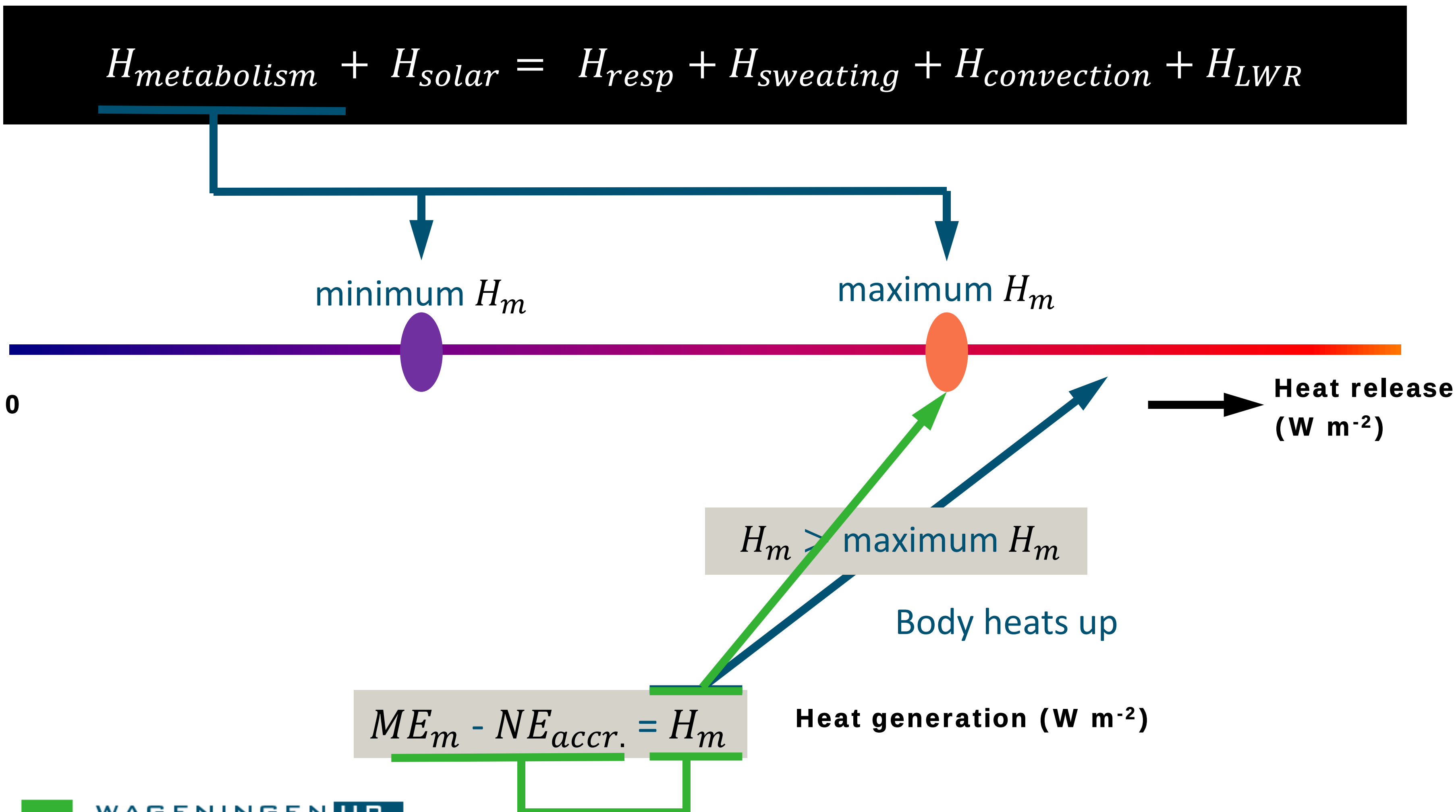


Methods (8) G x C interaction

$$H_{metabolism} + H_{solar} = H_{resp} + H_{sweating} + H_{convection} + H_{LWR}$$



Methods (8) G x C interaction



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Methods (9) Feed digestion

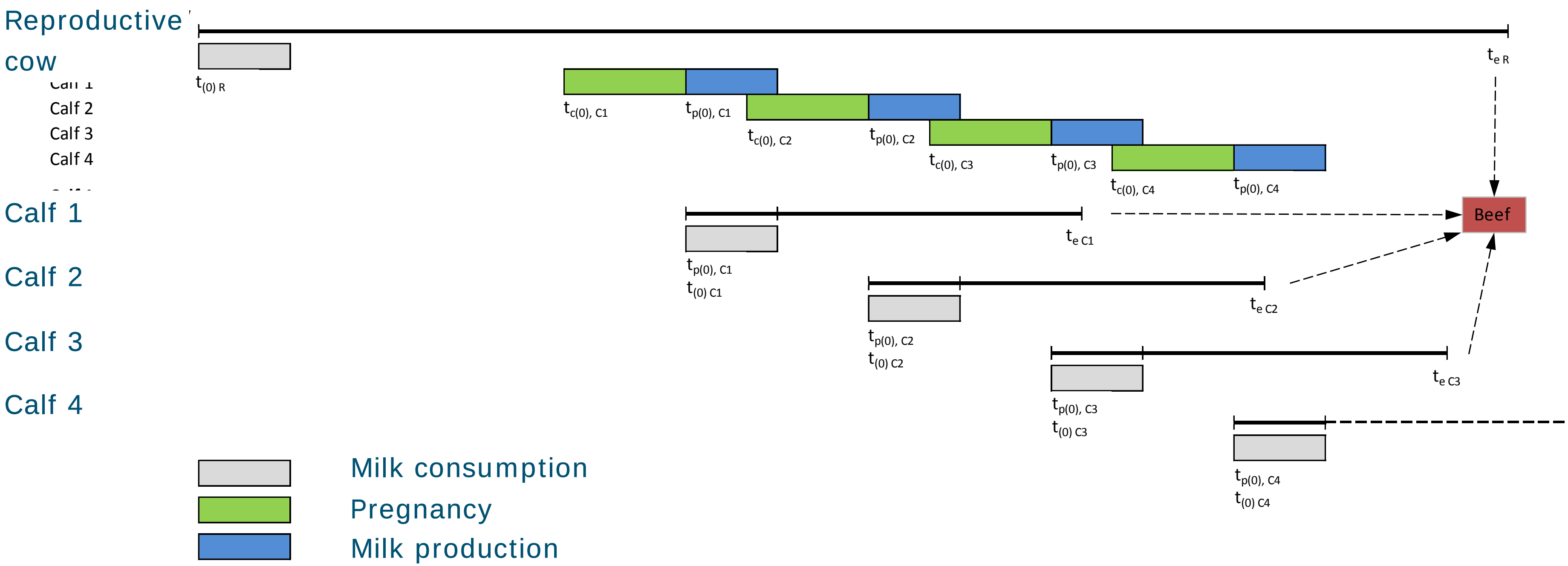
100 Megajoule ME_m day^{-1}= ? kg DM feed day^{-1}

- Adopted a feed digestion model
  - Includes a number of feeds
  - ‘Potential’ barley-hay diet
    - No limits to digestion capacity
  - Degradation and passage rates
  - Higher rumen fill → higher passage rate

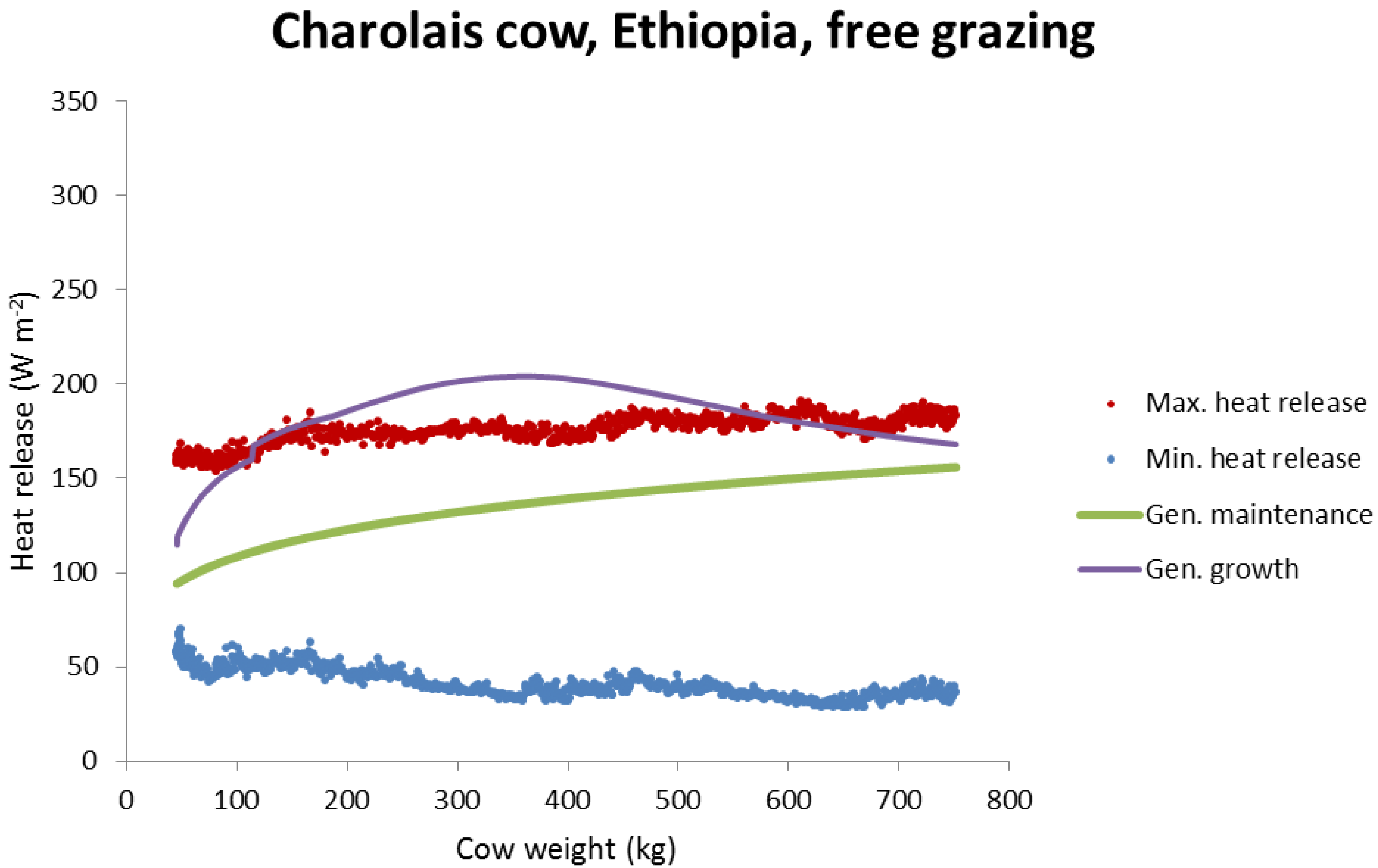
Chilibroste *et al*, 1997

Methods (10) Upscaling to herd level

- Potential production; from individual to herd



Results (1) Potential production



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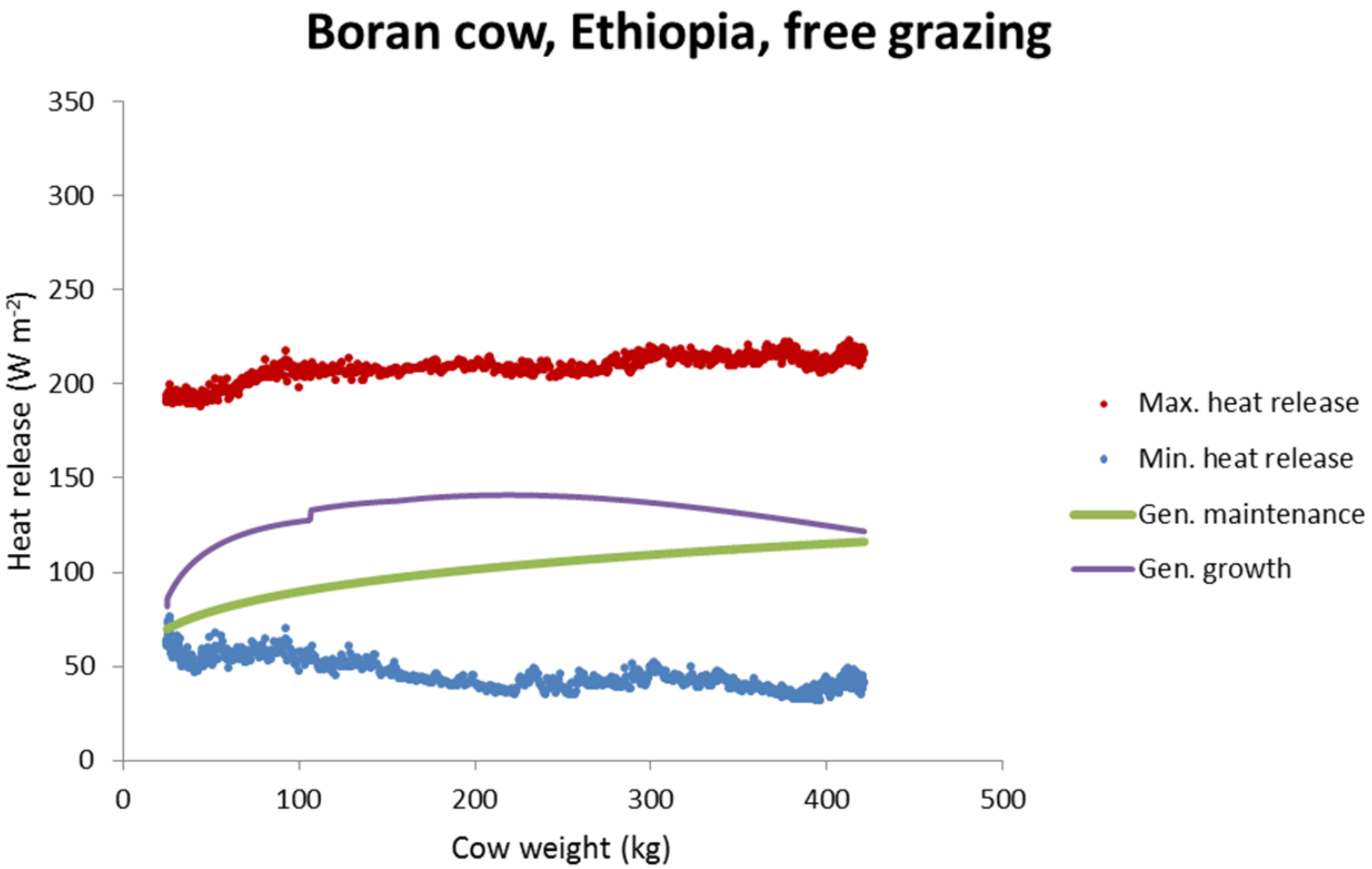
Results (2)



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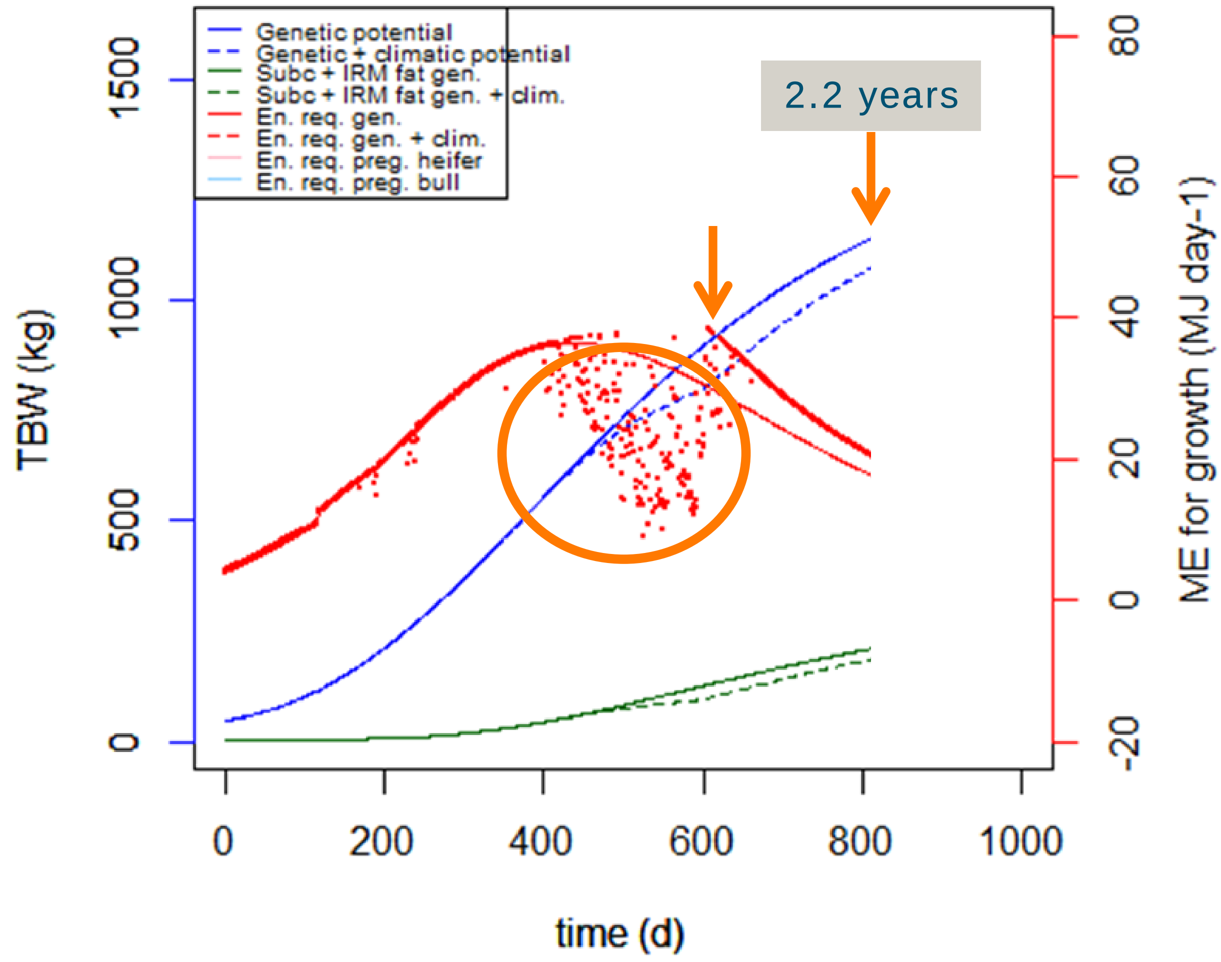
Results (3)

- Charolais bull, France



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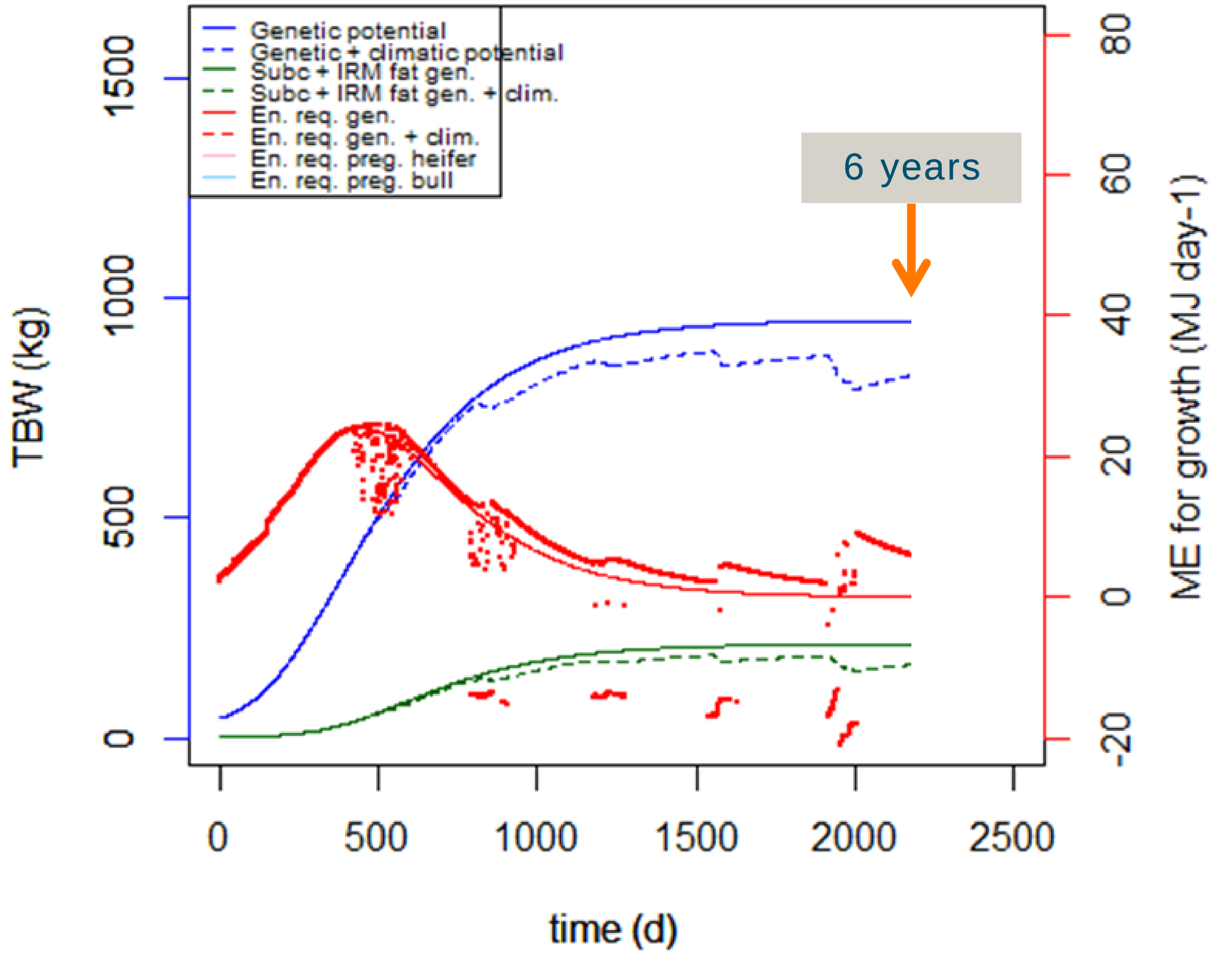
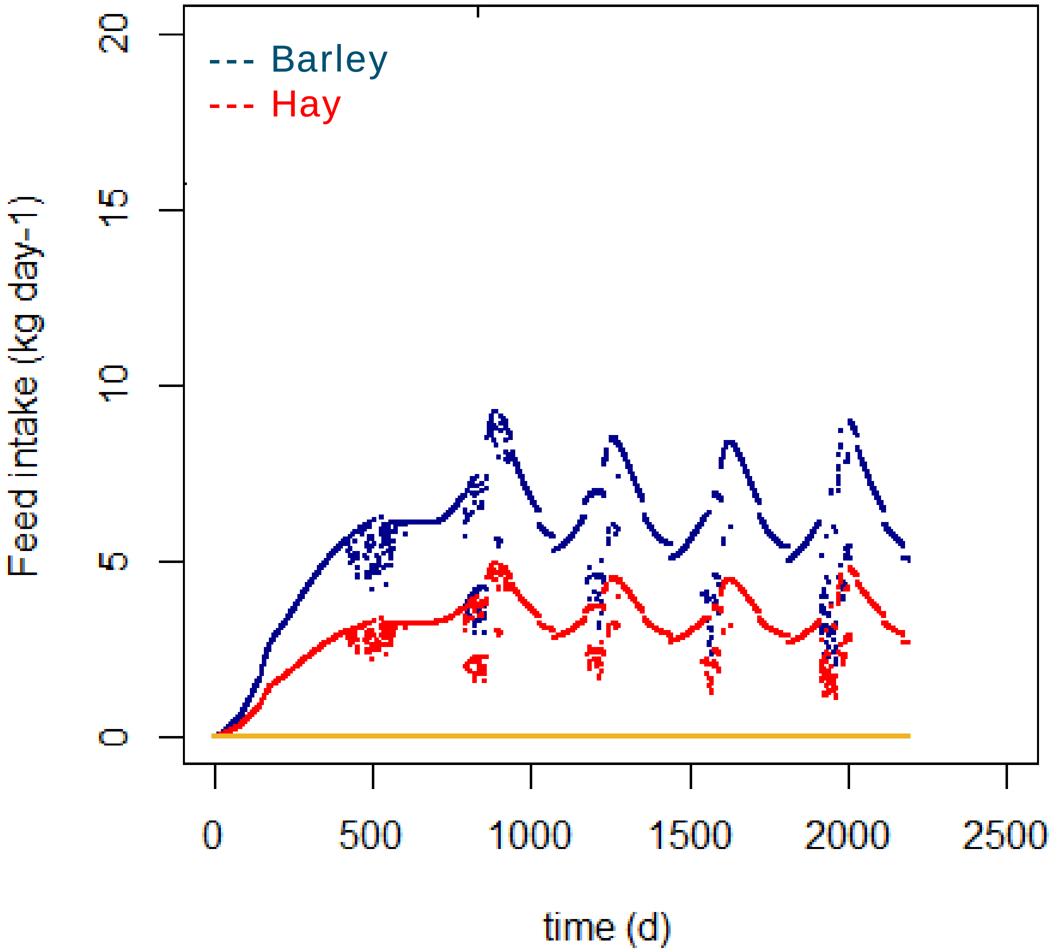
Results (4)

- Charolais cow, France



Results (5)

- Charolais cow, France



Results (6)

Scenarios for modelling potential beef production

- Charolais breed
- 4 climates:
  - Wageningen — The Netherlands
  - Charolles — France
  - Arba Minch — Ethiopia
  - Invercargill — New Zealand
- Cattle housed in stables
- Barley-hay diet
- No death of cattle, fertility = 100%.
- 4 calves per cow

Results (6) Charolais

Herd		Netherlands	France	New Zealand	Ethiopia
Reproductive	Pot. beef prod.[1]	83.5	74.3	86.9	47.8
	FCR[2]	38.3	41.6	37.5	52.5

[1] kg beef per cow per year

[2] Feed Conversion Ratio

[3] kg beef per calf per year

[4] kg beef cow + calves per year

Preliminary conclusions

- First quantitative application of the production ecological principles to animals.
- Model simulations show that potential production of cattle is greater in a climate to which the breed is adapted than a sub-optimal climate.

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Thank you!

www.yieldgap.org

www.wageningenur/en/basis

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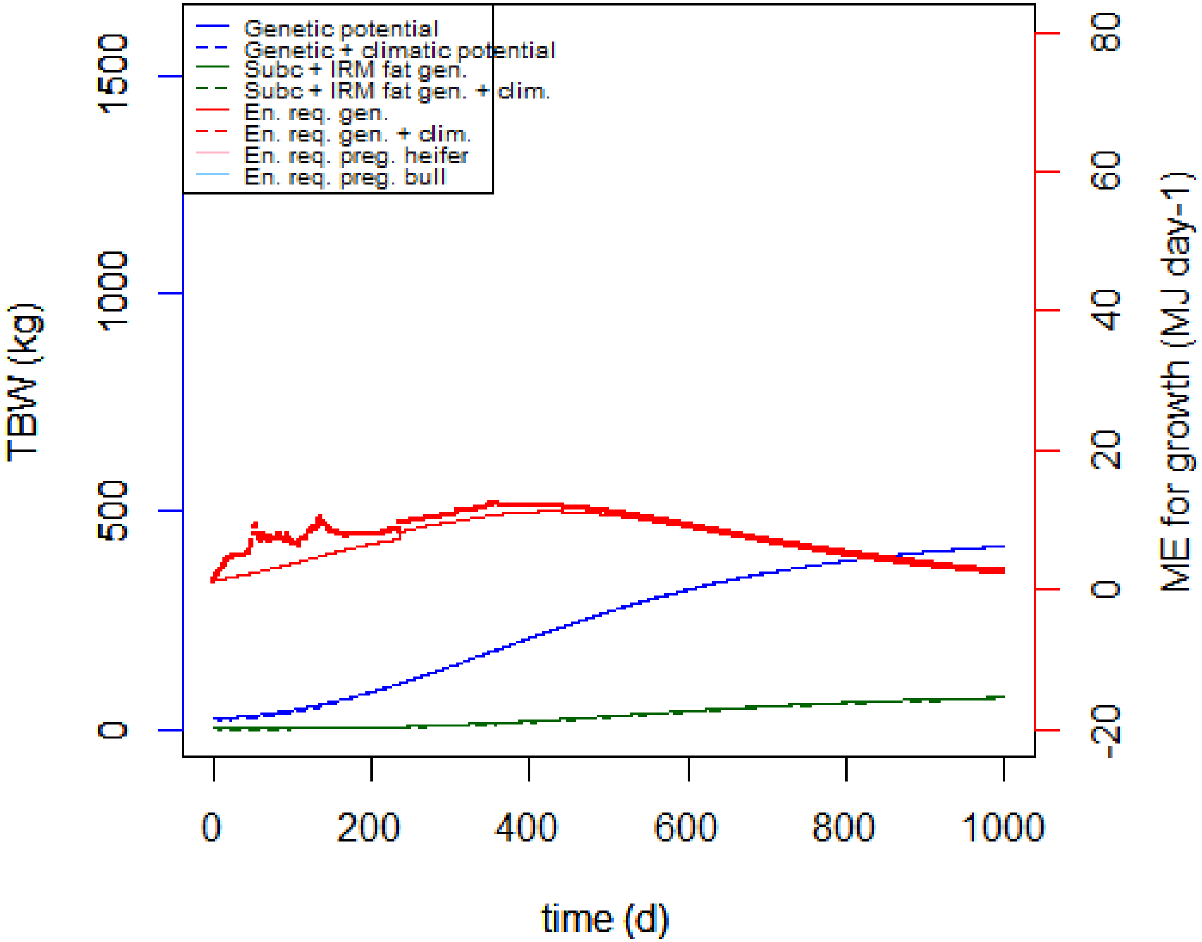
Boran in New Zealand



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