

Lifetime nitrogen efficiency of dairy cattle: Model description and sensitivity analysis

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Introduction

Climate change affects dairy production in various ways:

- drought → feed quality and quantity
- heat stress → animal performance and health
- diseases → opportunity costs

Lifetime N use efficiency

- most of our efforts have been animal oriented:
diet → milk N use efficiency (MNE)
- other elements (management, disease, fertility)
→ lifetime N use efficiency (LNE)

Objective:

To develop a herd model that includes elements of management, production and disease to evaluate overall lifetime efficiency of dairy cattle

Material and Methods

Model description

The LNE model consists of six primary compartments (Figure 1)

- N loss or gain is calculated in each compartment
- lifetime N loss or gain is calculated using the inputted replacement rate of the herd (r) and the number of cows (n)
- overall efficiencies are calculated as follows:

$$\text{RepINE} = N_{\text{ReplBW}} / (N_{\text{ReplBW}} + N_{\text{Lrepl}})$$

$$\text{LactNE} = N_{\text{O milk}} / (N_{\text{O milk}} + N_{\text{Llact}})$$

$$\text{LNE} = N_{\text{Prod}} / (N_{\text{Prod}} + N_{\text{Lrepl}} + N_{\text{Llact}})$$

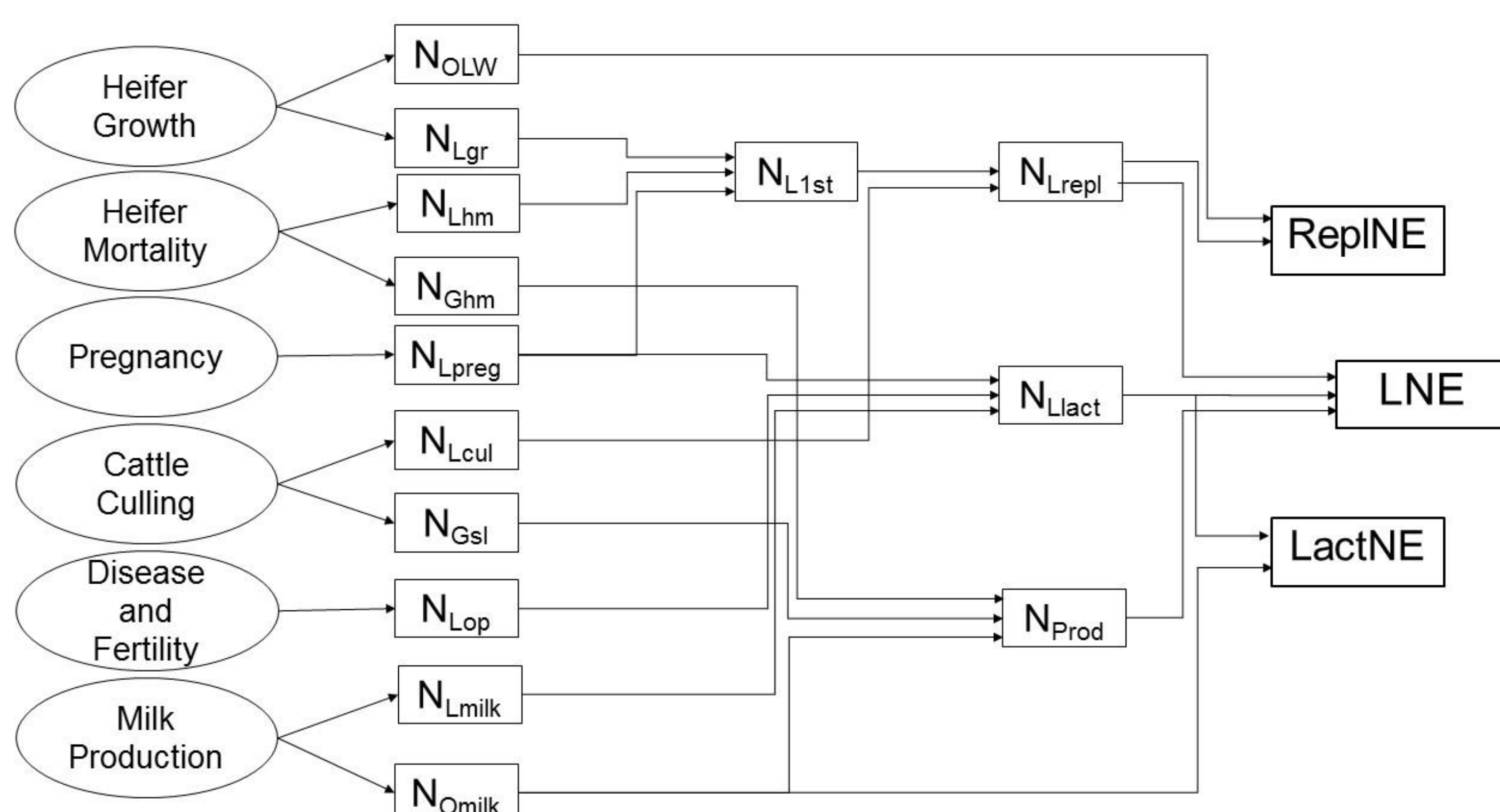


Figure 1. Schematic description of the lifetime nitrogen (N) use efficiency model: (N_{OLW} : N retained in replacement heifer; N_{Lgr} : N loss for heifer growth; N_{Lhm} : N loss due to heifer mortality; N_{Ghm} : N gain due to heifer mortality; N_{Lpreg} : N loss in pregnancy; N_{Lcul} : N loss due to cattle culling; N_{Gsl} : N gain due to cattle slaughter; N_{Lop} : Opportunity N losses; $N_{\text{O milk}}$: Milk N output; N_{Lmilk} : N loss for milk production; N_{L1st} : N loss till 1st calving; N_{Lrepl} : N loss for replacement cattle; N_{Llact} : N loss in lactation; N_{Prod} : Produced N; RepINE: replacement N use efficiency; LactNE: lactation N use efficiency; LNE: lifetime N use efficiency).

Sensitivity Analysis

Monte Carlo simulation using @Risk version 7 (Palisade):

- A default UK farm was constructed based on literature data
- Diets for heifers were formulated with the Cornell Net Carbohydrate and Protein System
- Probability density functions were fitted to inputs assuming normal distributions
- Frequency distributions with 10,000 iterations were calculated

Results

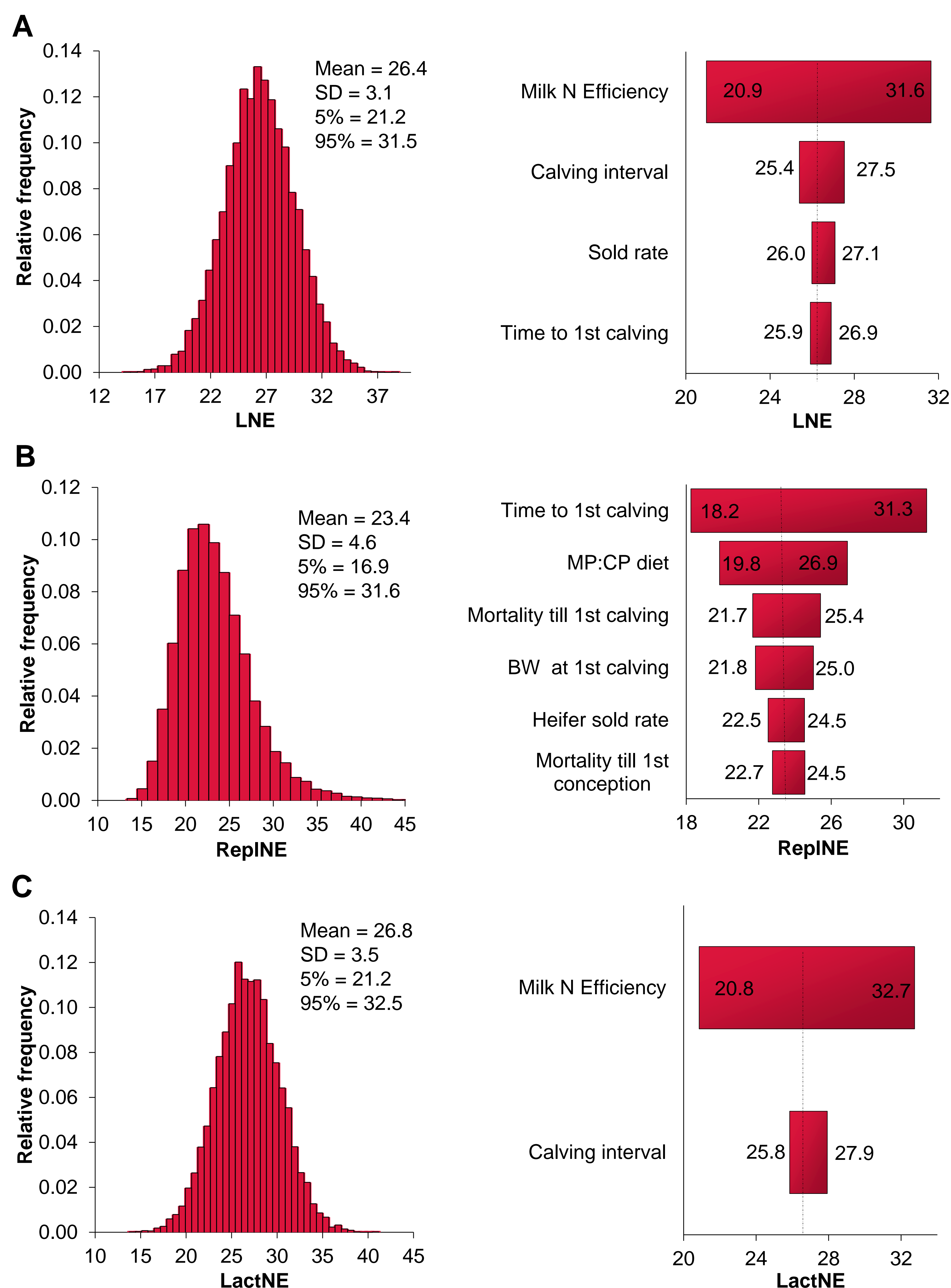


Figure 2. Frequency distributions and tornado diagrams showing the change in output mean for: (A) lifetime N use efficiency (LNE), (B) replacement N use efficiency (RepINE), and (C) lactation N use efficiency (LactNE)

Conclusions

- The dominant effect of MNE on LNE was verified
- We detected several other variables that also influence LNE, but to a lesser extent
- The LNE model is sensitive enough to quantify effects of different climate change scenarios through their effects on diet, health, and growth

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